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AUTOMATIC TEST EQUIPMENT

FINAL REPORT

Sperry Corporation
Sperry Support Services
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FOR

Ground Equipment and Missile
Structures Directorate
U.S. Army Missile Laboratory

28 February 1980

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents an overview of recent activities within Industry and the Department of Defense on Automatic Test Equipment (ATE). A review of ad hoc projects both within the services and jointly with industry is presented beginning with the Electronic Test Equipment Task Force established in 1974. A brief description of the major ATE systems in use by the Navy and Air Force together with a more detailed description of existing and planned Army ATE is presented. The report concludes with the need to emphasize Built-In-Test Equipment in future Army missile systems.

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1.0 INTRODUCTION

This report presents the findings of the project performed for the U.S. Army Missile Command (MICOM) on the industrial/government state-of-the-art in Automatic Test Equipment (ATE) design as it pertains to ATE for missile systems. This effort was performed under Work Order Number 40, Delivery Order 35 of Contract DAAK40-79-D-0020.

Close coordination was maintained with the Sperry MATE (Modular Automatic Test Equiment) Program Office to assure that there was no duplication of effort between the MICOM ATE Program and the USAF MATE Program.

2.0 BIBLIOGRAPHY

The initial effort on this project has been the identification of specific reports and documentation that pertain to the MICOM task. The Defense Technical Information Center (DTIC), formerly the Defense Documentation Center (DDC), prepared three bibliographies using the following search terms:

- Automatic Test Equipment - Missile Systems
- Automatic Test Equipment
- Automatic Test Equipment - NASA

These bibliographies identified approximately 750 reports within the search categories.

A two- or three-level search strategy was used by DTIC in developing the bibliography. The Automatic Test Equipment - Missile Systems bibliography, used a three-level search. An abbreviated example of the search terms used for that bibliography is as follows:

<u>First Level Search Terms</u>

Automatic
Automatic Test Equipment

Second Level Search Terms

Automatic Test Equipment
Frequency Analyzers
Oscilloscopes
Pulse Analyzers
Signal Generators
"Etc."

Third Level Search

Guided Missiles
Missile Systems
Multipurpose Missiles
Surface-to-Air Missiles
Surface-to-Surface Missiles
Weapon Systems
"Etc."

The state-of-the-art has advanced so rapidly in the ATE field that reports dated 1975 or earlier were, as a general rule, not obtained as they were basically considered to be of little value.

The Redstone Scientific Information Center (RSIC) was the focal point for obtaining reports identified in the bibliography reports. In a few cases hardcopies of documents were obtained from RSIC. However, in the majority of instances the report was either not available or existed in microfilm only. Hardcopies were ordered directly from DTIC and took an average of 20 days to receive. Limited and/or classified reports were ordered but have either not been received as of this report date or took in excess of 45 days to receive. The delay in receiving reports from DTIC has presented a major problem which was partially aleviated by obtaining the necessary documentation from the Sperry MATE Program.

3.0 INDUSTRY AND DOD ATE PROJECTS

Serious past problems associated with the acquisition and use of Automatic Test Equipment (ATE) within the Department of Defense have resulted in

numerous ad hoc projects and/or programs both within the services and jointly with industry. The more significant of these projects are discussed in this section.

3.1 The Electronic Test Equipment Task Force

One early effort was "The Electronic Test Equipment (ETE) Task Force of the Defense Science Board." The purpose of the ETE Task Force, which was established by DOD on October 25, 1974, was "to examine the greater use by the DOD of privately developed, commercially available off-the-shelf electronic test equipment, including modifications thereof, with the goal of achieving economy and reliability benefits for the several Armed Services and to recommend policies for procedures which will maximize these benefits."

The Task Force approached its work by comparing private business methods with DOD methods for acquiring electronic test equipment.

The Task Force met numerous times during 1975, and nearly all members attended every meeting. In each case when a member could not attend, he was represented by a person with authority to speak for him. At these meetings, the general public participated in the discussions.

Three Working Groups were formed--Requirements, Procurement Practices, and Logistic Support. These groups held many meetings, visited various repair and calibration facilities, and heard presentations by selected agencies and groups. They also evaluated a great deal of information submitted by industry and government.

For purposes of the ETE Task Force report, electronic test equipment included all electronic devices used to measure, gauge, test, inspect, diagnose, or otherwise examine materials, supplies, and equipment to determine compliance with requirements established in technical documents. Off-the-shelf electronic test equipment (OTS ETE) is that electronic test equipment which is a developed product in regular production sold in substantial quantities to the general public at an established catalog price. Modified OTS ETE is any such equipment that has been modified even to a minor extent, such as by the addition of a military nameplate.

3.1.1 ETE Task Force General Conclusions

Study, analysis, and professional judgement led the ETE Task Force to conclude that:

- Collectively, private firms buy more ETE for their own use than the Military Services and major weapons systems contractors buy for defense use.

- Based on consideration of lifetime costs, ready availability, and reliability of equipment performance, private firms prefer to buy off-the-shelf electronic test equipment (OTS ETE).

- When the Military Services buy ETE, they often use or go to the great expense of preparing a Military Specification or other special purchase descriptions that precludes the purchase of highly reliable, competitively priced, and readily available OTS ETE. In many cases, the Military Services go through a costly, time-consuming process when a suitable item of OTS ETE could be obtained through a simplified procurement process to fulfill the essential military need.

- The use of Military Specifications tends to freeze designs in a field noted for its dynamic change. As a result, much of the ETE newly procured by the Military Services fails to take advantage of advances in design embodied in the latest OTS ETE being produced in the United States and abroad.

- Spare and repair parts manufactured to Military Specifications or other special design specifications tend to be more costly and take longer to procure, produce, and accept than OTS ETE parts that perform identical functions. Since many parts manufactured specially for the Military Services are not interchangeable with their commercial counterparts, large reserve inventories must be established and maintained to ensure that the parts will be available in the event of a national emergency.

- The Military Services tend to use highly complex, expensive networks of depots to distribute both specially designed and OTS ETE repair parts. To a very large extent, the military supply networks tend to duplicate the commercial network for the distribution of OTS ETE. Use of military depot systems rather than the commercial network for distributing OTS ETE repair parts far more than doubles the cost and often prolongs the time taken in providing such parts to the eventual user.

- The Military Services usually fail to take full advantage of manufacturers or other readily available commercial sources for the repair and calibration of OTS and other ETE.

- As a result of the foregoing, the Military Services pay more than private firms for the purchase and logistic support of ETE of equal value, availability, and reliability.

- The main reasons why the Military Services pay more and wait longer for ETE and its logistic support appear to be that the Military Services tend to overspecify performance requirements for ETE and military procurement regulations, policies, procedures, and practices tend to delay and burden the acquisition process and thereby inhibit the purchase of OTS ETE, the use of OTS repair parts, and the use of commercial repair and calibration facilities.

- The dearth of cost accounting data in the Military Services tends to hide the full impact of the indirect and overhead costs associated with the acquisition and logistic support of equipment built to Military Specifications and special purchase descriptions.

3.1.2 The Magnitude of Potential ETE Savings to DOD

The ETE Task Force estimated that savings on the order of $80 million per year would result from prompt and orderly implementation of its recommendations. In large measure these savings may be achieved through greater use by DOD of privately developed, commercially available off-the-shelf

electronic test equipment (OTS ETE). The following potential savings are based on conservative estimates using the best available information:

- The Task Force recognized the serious lack of an adequate DOD cost accounting system and the lack of valid cost data. This inability to provide operational cost visibility may make it very difficult to identify specific savings that would result from implementing specific Task Force recommendations. Nonetheless, potential savings were estimated, and the estimates are believed to be accurate by the ETE Task Force.

- The Task Force also believed that although several of the recommendations may appear to increase costs as a result of changing current practices, there should be offsetting benefits. For example, Recommendation 24 proposes establishing a single manager in each Service for electronic test equipment. Long-range benefits in terms of improved acquisition management, logistic support, and facility resource utilization should more than offset any short-range cost increases. In addition, the single manager will provide a means for assuring optimum implementation of other accepted Task Force recommendations. To date, only the Army has attempted to implement this recommendation.

- The Task Force also took into account the probability that some recommendations would be delayed or not fully implemented for various reasons. Therefore, allowance was made for this in the savings estimates.

- It should be noted that the potential savings were not all hardware-related but also included costs associated with such factors as people, facilities, transportation, handling, and warehousing. Therefore, several categories of funds and budget line items will be affected.

The potential savings were related by the ETE Task Force to its recommendations as follows:

Recommendation	Estimated Annual Savings*
Reduced writing of specifications	$10,500,000
Procurement simplification	6,200,000
Increased use of bid samples	15,000,000
Use of Army Preferred Item Lists	17,500,000
Greater use of commercial warranties	3,000,000
Direct use of commercial parts support	7,000,000**
Reduced calibration and repair facilities cost	8,500,000
Improved replacement procedures for older equipment	9,000,000***
Greater use of commercial manuals	1,200,000
Total estimated annual savings	$77,900,000

It should be noted that although only ETE, not ATE, was the subject of the ETE Task Force's investigations. Many of the recommendations, when implemented, would produce similar cost benefits to ATE procurements.

3.2 Industry Ad Hoc ATE Project for the Navy

The Quality Assurance Committee of the Aerospace Industries Association (AIA) and the Quality and Reliability Assurance Advisory Committee of the National Security Industrial Association Navy Liaison Panels jointly sponsored a meeting with the Navy Automatic Test Equipment Management and Technology Office (ATEMAT) on May 20, 1975, in Washington, D.C. The minutes of that meeting are summarized in AIA release AO-QAC 75-24 dated June 19, 1975. The recommendations from that meeting, both from industry and the Navy, were that

*In FY'75 Dollars
**Averaged over the first 12 years
***Averaged over the first 10 years. Annual savings reach $30 million after 8 years.

an Industry group be established and, working with Navy Technical Advisors, resolve many of the problems now being experienced in the automatic test equipment and related fields.

Improvement in the maintenance, testing, and repairing of Navy equipment in order to reduce logistic costs and increase equipment readiness are recognized objectives of the U.S. Navy. In October 1975, the Industry Ad Hoc Automatic Test Equipment Project for the Navy was formed. This project was given a charter to investigate 13 key areas of technical and management concern, encompassing the broad spectrum of present and future disciplines required to effectively use automatic test systems.

The Project consisted of a Steering Committee and 13 Task Groups, comprising 174 expert technical and management personnel from aircraft, electronic, test equipment component, and computer manufacturers as well as members of the academic community. The Steering Committee that guided this effort consisted of 17 members, each with an average of 24 years experience in all facets of automatic testing.

During the course of the project, a 1-week workshop was held in San Diego, California, in April 1976, to discuss the research, development, test, and evaluation aspects of new automatic test systems. This workshop was attended by approximately 400 people, representing industry, the Department of Defense, and the academic community. Working groups were established to discuss and obtain the opinions of this broad spectrum of people with regard to research, development, test, and evaluation (RDT&E) of new automatic test systems.

The establishment of the Ad Hoc Project and its investigations into automatic test systems were the direct result of the Navy's concern with the effectiveness of their present automatic test equipment and its associated software. The fleet complained that performance objectives were not being met because their automatic test equipment lacked capability, was unreliable, and was difficult to maintain; and because the lack of automatic testing was causing workload problems. The overall effect was that mission readiness was

being affected. The goal of the Project was to assess those complaints and generate a set of industry recommendations to the Navy that would identify specific areas where improvements could be achieved.

3.2.1 Conclusions

Automatic Test Equipment (ATE) was defined, for the Project, to mean all types of automatic and semiautomatic test, monitoring, and diagnostic systems and equipment. This definition was advanced by the Honorable John Bowers, Former Assistant Secretary of the Navy for Installations and Logistics.

The conclusions and recommendations presented in the Report represent many different viewpoints, meaning that they often overlap and sometimes conflict. One thing that industry totally agrees upon is that automatic testing is an extremely complex and dynamic technology that is absolutely essential to the support of today's Naval weapon systems. For example, most new digital systems are so complex that they cannot be tested without automatic test equipment. It is projected that in the near future all types of electronic equipment will require automatic testing. The primary motivation for utilizing automatic test equipment will then become one of technical necessity, rather than just the savings in personnel and the reduction in time to repair.

While automatic testing has made great strides in its technology in the last decade, much of it is not focused on the DOD's goals and objectives. The Navy has tended to depend on industry to develop automatic test technology or to incorporate technology development during the acquisition phase of a program. It is estimated that for every dollar the Navy spends on acquiring automatic test equipment, half a cent is spent on research, development, test, and evaluation in automatic testing. This compares very poorly with some of the leading electronics companies, who normally spend betewen 2.5 percent and 9 percent of their sales dollars on research and development. Considering the importance of automatic testing to the Navy and its impact on life-cycle costs, it is estimated that the ratio of dollars spent on automatic test equipment research and development to those spent on acquiring automatic test equipment should be in the range of 4 percent to 6 percent.

The management of automatic test systems at all levels has been handicapped by DOD managers' lack of understanding of automatic testing, and by their failure to make critical program decisions at timely and cost-effective points in the weapon system development process. It was also concluded that there is a lack of what might be called an "ATE Corporate Memory" in the Navy, which would allow the lessons learned from one program to be effectively applied to another.

Inadequate testability in weapon systems, from the circuit level upwards, has made automatic test equipment and test programs difficult and expensive to develop. To this day, there is no precise, quantitative definition of testability. Unless a real number can be assigned to testability so that it can be measured and evaluated, support costs will continue to increase and readiness will continue to suffer.

3.2.2 Recommendations

Figure 1 is a matrix of the five key recommendations assembled from all of the Project Task Groups. These recommendations are summarized in the following:

	A-1	A-2	A-3	A-4	A-5	A-6	A-7	B	C	E	F	H	I
	SOFTWARE	AUTOMATIC TEST GENERATION	DESIGN FOR TESTABILITY	PROPULSION, ELECTRICAL, AND AUXILIARY SYSTEMS MONITORING	NEW TECHNOLOGY	EDUCATION, TRAINING, AND MANAGEMENT	ADVANCED ATE CONCEPTS	ATE ACQUISITION PLANNING GUIDE	BUILT-IN-TEST DESIGN GUIDE	ATE DATA BANKS	ORMS	ATE INTERFACE	ATE SPECIFICATIONS REVIEW
IMPROVE ATE MANAGEMENT	X		X		X	X	X	X					X
PROVIDE ATE RDT&E PROGRAM(S)	X	X	X	X	X		X		X		X		
IMPROVE ATE STANDARDIZATION	X		X	X	X		X		X			X	
IMPROVE TESTABILITY		X	X		X		X		X			X	
ESTABLISH ATE CENTER(S)	X				X		X			X			

Figure 1. Key Recommendations

- Improve the management of automatic testing at all levels within the Navy. It is recommended that management decisions concerning automatic test equipment and built-in-test features be made at timely points in the equipment and weapon system development processes. The Navy should also institute an all-out effort to establish comprehensive training courses in automatic test technology for program managers, acquisition managers, and operational maintenance managers.

- Increase the level of Navy funding of research, development, test and evaluation in the field of automatic testing. A comprehensive program should be established with funded studies in all phases of automatic testing. These studies should include automatic test software, automatic test generation, built-in-test capability, design for testability, auxiliary systems monitoring, and operational readiness monitoring, as well as advanced automatic test technology and systems concepts.

- Provide selected standardization for certain areas of automatic testing. Of particular concern are automatic testing languages and software, testability criteria and design features, and several areas of new and emerging technology. Standards should be established for the interface between the on-line automatic test equipment and the Ships Data Multiplexing System. In the case of off-line automatic test equipment, the interface with the unit to be tested should be investigated for similar standardization.

- As soon as possible, define "testability" in a numerically precise and measurable manner so that it may become a design parameter instead of a design goal. Quantitative testability design features can then be required in every new technology development, including electronic, electromechanical, and mechanical systems, at all levels of design, and for both on-line and off-line conditions.

- Establish a Navy automatic test technology center (or centers) to provide Navy-wide coordination of automatic testing policy, technical

development, and program implementation. This center(s) should be staffed wtih a cadre of automatic-testing professionals who can provide Navy Programs and System Commands with policy guidance and technical information. What is more important, these centers would enable the lessons learned from previous automatic test equipment programs to be incorporated into current ones.

Appendix A contains summary task descriptions and the recommendations for each. These recommendations should be of great value to both the Navy and to industry in solving existing problems and should provide for cost-effective future of automatic testing and automatic test equipment.

3.3 Industry/Joint Services Automatic Test Project

Serious past problems associated with the use of automatic test equipment (ATE) within the Department of Defense gave rise in October 1975 to the Industry Ad Hoc Automatic Test Equipment Project for the Navy. This Project, under the sponsorship of 5 industry associations, was chartered to investigate 13 key areas of technical and management concern, including present and emerging technologies that impact effective use of automatic test systems.

Completion of the Navy Project, the participants in which were 174 technical and management experts from a broad cross-section of the academic and industrial communities, elicited a request in July 1977 that the Navy Ad Hoc Committee be rechartered to address Army, Navy, Air Force, and Marine Corps concerns. The resulting study is titled "The Industry/Joint Services Automatic Test Project."

The Project was organized around 17 task groups, charged with focusing on advanced test technology, acquisition support, and management considerations. An Automatic Test Conference and Workshop, held in San Diego on April 3-7, 1978, explored these 17 areas in depth, providing a forum through which the entire automatic test equipment community contributed to the conclusions and specific recommendations in the Project Final Report. The Project Final Report was initially scheduled for completion in early 1979 is now anticipated to be released in early 1980.

The Project was organized around five working committees. The following describes the Committees, the Task Groups within the committees, and their activities.

Committee I on Advanced Testing Technology was charged with addressing the technological aspects of the Project. It explored the various technical issues that relate to the overall problem of testing the military prime mission equipment of today and tommorrow.

The nine task groups into which this committee was divided recommended to the Joint Services key technical tasks, based on certain initial investigations, with a view to developing the technical base needed for military ATE support.

Task Group I.A. on Software explored novel and improved techniques relating to the design, implementation, verification, and operation of ATE system software. Elements addressed included compilers, drivers, operating systems, translators, firmware, and simulators.

Task Group I.B. on Automatic Test Generation explored such aspects as modeling techniques for analog circuits and improved generation methods for digital circuits. It also addressed the ultimate goal of combined analog and digital test generation.

Task Group I.C. on BIT/Design for Testability addressed the various methods by which the overall testability of prime mission equipment might be improved, since test effectiveness is directly related to testability. Topics explored included basic methodology, built-in-test, means of implementation, cost/weight/reliability trade-offs, and net benefits.

Task Group I.D. on Nonelectric Test covered such topies as failure-mode identification, failure predictors, qualified sensors, and performance monitoring.

Task Group I.E. on New Technology concerned itself with test technology for such areas as lasers, optical electronics, microwave devices, and radio-

frequency devices. As new technology appears in prime mission equipment, corresponding test technology must be available.

Task Group I.F. on Microprocessors explored the applicability of microprocessors and high-density logic to such functions as built-in-test, off-line fault isolation, and self-calibration. It also addressed reliability factors, critical-path testing, standardization of microprocessor classification methods, memory-testability improvement, and fourth-generation microprocessor applications.

Task Group I.G. on Advanced ATE Technology examined the overall ATE system concepts and defined a family of automatic test equipment from technical and management points of view. Technical considerations included system architecture, subsystem technology, and "blue-sky" approaches. Management considerations forcused on the family-of-ATE evolution process that maximizes ability to capitalize on lessons learned. Areas amenable to standardization and the feasibility of Joint Service Technology Centers are addressed. The systems approach is expected to provide synergistic benefits not attainable through isolated recommendations.

Task Group I.H. on ATE Interfaces explored the unit-under-test/ATE interface, the internal ATE system interface, and the very important man/machine interface--both audio and visual. Also addressed is the impact of interface requirements on software, testability, test-program-set development, system calibration, and automatic test program generation.

Task Group I.I. on Calibration explored the implication of calibration on automatic test equipment as well as on manual test equipment. Calibration cycles, self-calibration, automatic calibration systems, and self-test are some of the significant topics covered.

Committee II on Acquisition Support focused on four areas that have been persistent and costly problems to each of the military services. Systems engineering, training, test languages, and test program sets are addressed, with a view to developing a unified approach and recommending technical and management policies and guidelines for implementation of that approach.

Task Group II.A., System Engineering. Although automatic test equipment is a critical and costly asset in support of almost every weapon system, ATE cost and system engineering trade-offs and analysis are seldom considered in overall system acquisition. This Task Group recommended analytical tools, techniques, and methods for use in evaluating systems; and logistics support and acquisition of automatic test equipment appropriate to the Joint Services.

Task Group II.B. on Education and Training investigated ineffective training, which has been identified as a major contributing factor in many ATE-related problems. Recommendations for a new Training policy in terms of courses, curriculum, innovative media training methods, and improved operator/technician and management programs are identified.

Task Group II.C. explored Standardization of ATE Languages without limiting innovation in testing and with emphasis on test technology rather than on computer technology. Topics addressed included the feasibility of a family of languages, subsets of the language, language inadequacies, language-change techniques, compiler portability, and documentation requirements.

Task Group II.D., Test Program Set (TPS) consists of the application software, hardware, and associated operator instructions that are required to test a particular unit or units. TPS cost, effectiveness, and quality are escalating problems for the Military. The Task Group II.D. worked toward defining standard TPS elements and control methods, and recommended a common policy for all the Military Services.

Committee III on Management is charged with addressing the planning, procurement, deployment, and control of automatic test system resources.

The four task groups into which this committee is divided each address a specific issue having a bearing on the effective management of automatic test equipment.

Task Group III.A. on ATE Acquisition reviewed the ATE acquisition process from concept to deployment. Particular attention was given to such

matters as contractor-to-DOD transition, contractor perception of needs for greater acquisition efficiency, the applicability of "fly-before-buy" to automatic test equipment, and the reed for ATE corporate memory and data retrieval.

Task Group III.B. on Maintenance Planning and Concepts reviewed the planning of ATE support concepts, addressing levels of maintenance from organizational to depot/factory. Particularly stressed was interfaces between levels of maintenance, development of maintenance concepts, and alternative approaches to conventional support planning.

Task Group III.C. on Resource Management addressed the intermediate-level shop as a specific area for more efficient application of support resources. Since automatic test equipment represents a major investment at the intermediate shop, its use must be integrated with other available resources, including technicians, spares, repair facilities, and shop procedures.

Task Group III.D. on Benefits Analysis identified a basis for projecting what benefits will accrue from implementation of the recommendations of the Industry/Joint Services Project Committee. Techniques for the quantitative measurement of ATE payback were developed.

Committee IV on Conference and Workshop was charged with organizing and conducting the Industry/Joint Services Automatic Test Conference and Workshop held on April 3-7, 1978, in San Diego, California.

The Conference objectives were threefold:

- o To stimulate an exchange of ideas between Industry and the Military on technical, management, and acquisition-support aspects of automatic testing.

- o To make available to the ATE community a progress report on the Industry/Joint Services Automatic Test Project.

- To provide a forum through which the total ATE community can impact the Project Final Report.

Committee V on Publications is charged with coordination of all publication activities associated with the Industry/Joint Services Automatic Test Project. Its responsibilities include coordination of content, design, editing, and production.

The Conference and Workshop was held in San Diego, California, April 3-7, 1978, and was attended by approximately 820 people.

3.3.1 Conclusions

The Industry/Joint Services Automatic Test Project made two observations that applied to each recommendation. These were:

- Similar problems are experienced by all Services.

- Few problems can be traced to a single cause; rather, a high level of interdependency exists.

It was concluded that because of this interdependency, actions taken on implementing the recommendations in the management area will mutliply the potential for benefits from the technical recommendations. This interaction also exists between the disciplines of Integrated Logistic Support and Automatic Test Equipment. It was concluded that the actions outlined in DOD Directive 5000.XX, Acquisition and Management of Integrated Logistic Support for Systems and Equipment, are supported by the findings of the Project.

3.3.2 Recommendations

The Industry/Joint Services Automatic Test Project made 11 key recommendations. These 11 summary recommendations are the result of 110 individual recommendations made by the 17 task groups. These recommendations are presented in this section in order of priority. The importance placed on these recommendations by the Project is emphasized in the following quote from the Executive Summary:

"Unless we invest now to anticipate and solve tomorrow's problems, we will continue to react rather than control. We will settle for less operational readiness than we need, at a cost higher than we can afford."

From the time the Task Groups met to discuss recommendations until the final recommendations were developed, a period of 6 or more months elapsed. During this time a new technology thrust for very-high-speed integrated circuits has been initiated, and the use of microprocessors has accelerated. Both of these continuing events have an undefined impact on the final recommendations.

The following paragraphs discuss the 11 recommendations and include a brief description of the problem. This information has been taken from the Final Report, Executive Summary.

1. Organization, People, and Funding

   a. Problem: Despite an abundance of procedures, directives, specifications, and other documents governing maintenance planning, few complex weapon systems have been deployed with an adequate support capability. This paradox has its origin during the early phases of the acquisition process, when support authority is most needed but least effective, largely because resources are too easily allocated to more immediate problems.

   b. Recommendations:

      o Provide for an OSD-mandated policy which imposes supportability requirements for acquisition of military systems, starting at the conceptual phase.

      o Establish a focal point within the Office of the Secretary of Defense for advocacy and coordination of automatic-test-related matters.

- Implement the above-mandated policy at the individual Service level by establishing centralized organizations with appropriate accountability, budget control, and responsibility for interservice coordination.

- Provide career paths and motivation for retention of management and critical technical personnel, both military and civilian.

2. Military Equipment Design

   a. Problem: The ability to test military equipment efficiently is prerequisite to supportability. Testability, as a design discipline, is currently inadequate because there is no accepted method for measuring it and no mechanism for imposing and enforcing it during the equipment design phase.

   b. Recommendations:

   - Develop verifiable testability requirements.

   - Impose these requirements on the prime-system/automatic-test-system design process and take measures to ensure compliance.

3. Specifications, Directives, Controls, and Deliverables

   a. Problem: Logistic-support directives, specifications, and standards are not applied uniformly or early enough in the acquisition process. Contract Data Requirements items are redundant and duplicative across the Services, and have proliferated to satisfy individual requirements.

   b. Recommendations:

   - Impose standardized Contract Data and Automatic Test Requirements documentation as program planning and life-cycle cost control deliverables.

- Require appropriate tailored versions of Logistic Support Analysis/Logistic Support Analysis Record (LSA/LSAR) development procedures early in weapon-system acquisition.

4. Nonelectronic Test Development

   a. Problem: Lack of effective automated maintenance equipment currently results in degraded equipment availability, and excessive turn-around times and costs associated with logistic spare-parts reclamation.

   b. Recommendation:

      - Accelerate the application of automatic test in support of nonelectronic systems and equipment. Technology is available which can significantly improve readiness and fuel efficiency, and significantly reduce life-cycle cost and maintenance man-hour requirements.

5. Test Program Set Development and Management

   a. Problem: Although Test Program Set costs exceed hardware cost, they are less predictable and less controllable. Moreover, there is no common definition of what constitutes a Test Program Set among designers, suppliers, and Government agencies. As a consequence, the user receives a different support and maintenance data package of varying quality with each automatic-test acquisition.

   b. Recommendations:

      - Define and establish controls for acquisition and maintenance of Test Program Sets, including test software, interface hardware, and data.

      - Support the development of automated test-program-generation systems.

o Support ATLAS as the common Joint Services test language.

6. Automatic Test Technology Development

a. Problem: New-technology devices in developmental weapon systems pose test problems that cannot be solved using traditional test techniques. Support-equipment developers need advanced test techniques and advanced automatic-test system architectures appropriate to these increasingly complex test requirements.

b. Recommendations:

o Establish continuing technology-development programs in specific aspects of automated test where the payback potential is high.

o Support a technology-forecasting activity for timely identification of technology advances destined to impose new automatic-test requirements or to enhance automatic-test capabilities.

7. Data Banks and Models for Life-Cycle Costing, Logistics Support Analysis, and Technology Assessment

a. Problem: Within the Department of Defense, there are many similar but separate data banks, each with its own access procedures. The diversity of models and their implementation further weakens the integrity of the systems engineering process. The result is a less than optimum interchange of Joint Services and industrial information.

b. Recommendations:

o Establish common models and Logistic Support Analysis techniques tailored to the systems engineering process during various phases of acquisition.

- Establish a linking data-bank network to improve data commonality and the ability to use lessons learned across the Services.

8. System Software Development and Maintenance

a. Problem: The development of automatic-test system software is a complex process, which differs subtly from that for other DOD software. Unfortunately, there is no consistent, top-down understanding of the complex hardware/software relationships involved. As a consequence, cost reduction and control are ineffective, and software maintenance is unnecessarily hampered by the many versions of nonrehostable, proprietary software products that are developed.

b. Recommendations:

- Rigorously define software life cycle and requirements for configuration control and quality assurance.

- Develop guidelines for configuration management and for the maintenance of automatic-test system software.

9. Metrology and Calibration

a. Problem: The establishment of test-system tolerances and accuracy requirements is hampered by the absence of technical criteria and discipline. Typically, test-system specifications are characterized in terms of component measurement and stimulus units. Few automatic test systems have been specified to a common reference point or take into account the effects of interfaces and adapters. The consequences: trial-and-error software changes, arbitrary accuracy derating, and unnecessary removal of units for calibration.

b. Recommendations:

- More actively involve Metrology/Calibration Centers at an early stage in automatic-test design and support functions.

- Involve the National Bureau of Standards in basic measurement standards and support research in technique development for in-place traceability.

10. Training

a. Problem: The effective skill levels of the automatic-test operator and maintenance technician are increasingly overwhelmed by the requirements of contemporary technology. Supervisor training is particularly weak and, aggravated by lack of motivation, results in a high rate of turnover among the better people. Training still relates to basic skills and traditional training methods, creating a mismatch between the instructional methodologies used and the highly sophisticated equipment involved.

b. Recommendations:

- Plan, formalize, develop, and fund innovative approaches to the training of support-equipment operators, maintenance technicians, and shop supervisors.

- Establish formal training courses for personnel at all levels -- acquisition managers, engineers, and technicians.

11. Maintenance Shop Productivity

a. Problem: The Maintenance Shop Supervisor is hampered in his management of support equipment resources by the absence of real-time data on such items as status, priority, production, manning, and inventory; automatic processes cannot be efficiently managed through notes made on the back of an envelope with a stubby pencil. Contemporary automatic test equipment requires a controlled environment and a stable power source for proper operation. It contributes an excessive level of added acoustic noise to the work area, and currently suffers from excessive downtime for calibration and repair, as well as from too many and too complex interface devices.

b. Recommendations:

- o Improve support-equipment design and system performance by better integrating such specific Integrated Logistic Support elements as reliability, maintainability, and human factors.

- o Establish career paths and provide adequate incentives to ensure retention of automatic-test trained and experienced personnel, both military and civilian.

- o Develop and implement a real-time-management-information function under local control, to service the larger, automatic-test-equipped maintenance shops and to monitor productivity.

- o Integrate facility environmental needs into shop-site planning.

3.3.3 Follow-On Activities

The Industry/Joint Services Automatic Test Project represents, conservatively, a 45 man-year effort of study. The success of the Project has been acclaimed even prior to the release of the final report.

In response to a request from the Joint Logistic Commanders (JLC) Panel on Automatic Testing, the National Security Industrial Association (NSIA) has decided to sponsor the continuation of this vital liaison between industry and government through the establishment of an Ad Hoc Automatic Testing Group. It is anticipated that many of the participants in the new group will be a carryover from the previous project, thereby providing continuity of effort.

The prime purpose of the Ad Hoc Automatic Testing Group is to provide assistance and guidance to the JLC A.T. Panel in implementing the many recommendations of the Industry/Joint Automatic Testing Project.

A Steering Committee meeting for the Automatic Testing Ad Hoc Group was held on January 23, 1980. Both Steering Committee Members and Steering Committee Advisors attended the meeting. Chairman of the Conference Arrangement Committee and the Program Committee Chairman presented their program recommendations to the Steering Committee for review and approval.

The first major activity planned for the new group is a Conference/ Workshop to be held in San Diego the week of June 7, 1980. Eleven major subjects recommended by the Joint Logistics Commanders Automatic Test Panel will be covered. Each session will have joint chairmen representing both industry and the military.

As indicated above, the prime purpose of this Ad Hoc Automatic Testing Group is to provide both assistance and guidance to the Joint Logistic Commanders Automatic Test Panel in the implementation of the recommendations made by the Industry/Joint Services Automatic Testing Project. This is a VERY significant step and, if carried out with cooperation of the Services, can result in a unified appoach to ATE, its acquisition and effective utilization. Besides the obvious cost savings to be realized, the weapon system utilization should increase thereby improving readiness. Through this Joint Military/Industry action, the many preplexing problems which hampered effective utilization of Automatic Test Equipment should be resolved. This effort should be closely monitored by all groups involved in ATE.

3.4 The Army Task Force on Automatic Test Support Systems

The U.S. Army's Automatic Test Support System (ATSS) Task Force is the direct result of the Army establishing the Office of Project Manager, Automatic Test Support Systems (PM ATSS) in July 1976*. This office embarked on the development of standards for ATE hardware and software. The implementation of an ATE standardization policy gave rise to the following questions:

1. Should standardization be established at the commodity command or Army-wide level; i.e., should the Army employ two or more types of general purpose testers or only one?

*In February 1979, PM ATSS changed its name to PM, Test Measurement and Diagnostic Systems (TMDS).

2. At what points in time should standard testers and the Army standard language be introduced?

3. Who will manage the development and configuration control of the standard mechine(s) and test language? At what level of detail will central management end and commodity and PM management begin?

4. How quickly can small suitcase testers be introduced to improve readiness in the division and reduce the need for large GS ATE?

The need for prompt decisions on these and other issues related to ATE standardization resulted in a directive issued in December 1976 by DARCOM Headquarters establishing a TRADOC/DARCOM Automatic Test Support Systems Task Force. This Task Force convened on January 10, 1977 and terminated on March 24, 1977 at Fort Monmouth, New Jersey.

To provide guidance for the Task Force effort and a review of the results of the investigation, a steering group was established. Members of the steering group were general officers representing DA, TRADOC, and DARCOM; representatives of the DOD, the Air Force, and the Navy; and consultants. Industry was not represented on this task force. However, the task force conducted a survey of industry to assess present ATE capabilities and held numerous discussions with many companies involved in various aspects of ATE.

General guidance was provided by DARCOM for assessment of the current Army ATE posture and development of an optimum ATE acquisition strategy for the future. Specifically, the Task Force was organized to investigate the technical feasibility, employment concepts, and operational desirability of developing a family of Automatic Test Support Systems to be used for the maintenance of Army materiel. This included formulation of interim and long-range ATE approaches for major subordinate commands and program managers and a plan for future ATE development and acquisition.

The Task Force was divided into four groups, concerned, respectively, with Integration, Capabilities, Materiel Developer Requirements, and Doctrine/ Training. These groups defined and outlined the "key issues" assigned to them,

accumulated and analyzed data, and summarized the results in reports, charts, matrices, and tables. These summaries were exchanged between groups for further analysis and comment. The Integration Group (representatives of TRADOC, DARCOM, MSCs and PMs, and AMSAA) then synthesized the results of the analyses and formulated the conclusions and recommendations presented in a report.

A list of major decision issues was compiled on the basis of DARCOM guidance and judgements made by members of the Task Force. The determination of answers to these questions became the major objective of the study. A list of these questions follows:

1. What degree of standardization should the Army seek; i.e., should one machine or family of machines become Army-wide standards or should each commodity command establish its own standard machine or machines? Alternatively, should each program buy or develop special or general purpose ATE suiting his needs?

2. If Army-wide standardization is undertaken, what family of hardware should be selected? Should the ATE selected be a Government-developed, Government-owned design or off-the-shelf commercial hardware? What degree of ruggedization is required to meet mobility and environmental requirements?

3. At what points in time should Army standard ATE and the standard test language be introduced?

4. What is the appropriate mix of ATE types for each type of general support shop; i.e., what types of more specialized testers should be included in the standard family to supplement the large general purpose machine?

5. How should ATE development and standardization be managed? What should be the relationships between concerned activities in this process?

In consideration of the breadth of the assigned tasks and the limited time available, the decision was made by the Task Force to limit its 2-month effort to issues 1., 2., 3., and 5., leaving the question of ATE mix for future investigation. Other problem areas, excluded from intensive examination for the same reasons, were the applications of ATE at direct support and organizational levels and the cost-effectiveness of the current doctrine requiring printed circuit card repair at the general support shops.

These decisions, in effect, limited the 2-month effort of the Task Force to consideration of large general purpose testers employed at general support and depot operations. The assumption was made that there is sufficient need for the general purpose tester to justify at least one machine of this type in each of the missile, communications electronics, and avionics general support shops. This assumption is supported by the selection of a general purpose machine by a number of PMs and by the fact that expected shop work loads contain a sufficient number of complex, low-density units under test (UUTs) to establish an area of usefulness for the large machine.

3.4.1 Conclusions and Recommendations

The Task Force Final Report on Automatic Test Support Systems (ATSS) contains conclusions, recommendations, and unresolved issues. However, this information was not included in the sanitized, unclassified version of the report.

4.0 EXISTING MAJOR ATE SYSTEMS

This section is intended to provide a brief overview of major ATE systems in use by the Navy, Air Force, and NATO.

4.1 Navy ATE

The U.S. Navy has developed a large scale ATE system called the Versatile Avionics Shop Test (VAST) System to provide a general-purpose, intermediate-level maintenance capability for the Navy's avionics equipment.

The VAST System is a second-generation test system incorporating state-of-the-art improvements. It is a computer-controlled, general-purpose test system providing the broad range of stimulus and measurement capability required for automatically testing and troubleshooting aircraft avionics equipment.

The basic reason for the development of the VAST was for the Navy to meet the problem of increased complexity of avionic systems and special support equipment within the limited space capabilities of the aircraft carrier. The evolution of the VAST started through a study entitled "Naval Avionics Support Equipment Appraisal" sponsored by the Bureau of Naval Weapons, now NAVORD. This study recommended the following:

- Develop a general purpose computer-controlled test system which can be adapted to changing avionic shop test requirements and lower the technical skill level required.

- Promote avionic design to be compatible to automatic test equipment (ATE) maintainability features.

- Make increasing use of built-in test equipment (BITE).

The VAST System's hardware is made up of three major subsystems: (1) the computer, (2) the data transfer unit, and (3) the stimulus and measuring section.

The computer subsystem is made up of a control computer, magnetic tape units, and an input/output console. The data transfer unit is made up of the display panel, keyboard panel, and maintenance panel. The stimulus and measurement section is made up of building blocks, unit under test (UUT), interface panels, and station cabling.

Perhaps the key to the versatility of the system is the building block section. This section is made up of 45 different blocks which contain various types of electronic equipment which can simulate and record various types of

conditions required to test the avionics of various aircraft. Some of the building block equipment is listed below.

<u>VAST Building Block Equipment</u>

RF Test Point	Pressure Generator
Control Switch	Function Generator
Digital Multimeter	Impedance Meter
Frequency and Time Interval Meter	Low Frequency Wave Analyzer
Digital Word Generator	Nanosecond Pulse Generator
Delay Generator	Pulse Generator
RF Amplifier, 95 Hz-2 GHz	Spectrum Analyzer
RF Amplifier, 2-4 GHz	Peak Power Meter
RF Amplifier, 4-8 GHz	RMS Voltmeter
RF Amplifier, 8-12.2 GHz	Noise Figure Meter
Signal Generator, 0.1 Hz-50 kHz	Average Power Meter
Signal Generator, 10 kHz-40 MHz	Programmable Oscilloscope
Signal Generator, 20-500 MHz	Ratio Transformer
Signal Generator, 0.95-2 GHz	Low Voltage DC Power Supply
Signal Generator, 2-4 GHz	DC Power Supply, 22-32 Volts
Signal Generator, 4-8 GHz	DC Power Supply, 30-500 Volts
Signal Generator, 500 MHz-1 GHz	DC Power Supply, 0.5-1 kV
Signal Generator, 8-12.4 GHz	DC Power Supply, 1-20 kV
Signal Generator, 12.4-18 GHz	AC Power Supply
Feedback Simulator	Precision Resistive Load
Synchro/Resolver Standard	High Power Resistive Load
Phase Sensitive Voltmeter	

The VAST System also has self-test capability at one of three levels: (1) auto-check, (2) self-check, and (3) self-test. This helps to assure the overall reliability and ease of maintaining this complex automatic test system.

The VAST System is designed to be used at the Avionics Shop level as opposed to the flight line or organizational level. This means that faulty avionic or subsystems or "black boxes" are removed from the aircraft and tested on the VAST. The VAST then isolates the fault down to the module level so that replacement of the defective module can be made.

4.2 Air Force ATE

4.2.1 The Air Force General Purpose Automatic Test System (GPATS)

GPATS was originally conceived as a general purpose ATE system that would be utilized as ground support for the more advanced U.S. Air Force aircraft. The first utilization of GPATS was for the avionics of the F-111A at the depot level. As the GPATS Program evolved, it became apparent to the Air Force that GPATS would not prove cost effective for all units to be tested.

GPATS has the capability to test 80 to 85 percent of today's analog avionics. However, GPATS does not have digital testing capability which is a serious drawback to the original concept of a general purpose ATE system for aircraft.

4.2.2 Modular Automatic Test Equipment (MATE) Program

In the recent past, the Air Force System Program Office (SPO) had the responsibility of specifying, developing and acquiring initial test equipment as part of the weapon system package. For cost avoidance reasons, the Air Force specified the use of existing test equipment for new aircraft wherever technically and economically practical. It has become apparent that requirements exist to further reduce cost in the test area by technically addressing increased commonality of test equipment across aircraft subsystems and by addressing cost effective management tools. Historically, problems in these areas have concerned inadequate coordination of the concurrent development of test equipment and avionics. Difficulties arose due to poor definition of interface and test requirements. The overall result of these development problems has been a lack of confidence in the resultant test equipment and an inability to compete previously developed equipment due to the lack of good interface and test requirement documentation.

In an attempt to reduce these problems confronting the SPOs, the USAF Program to develop a family of Modular Automatic Test Equipment (MATE) has been established. It is expected that the MATE R&D efforts will provide future weapon systems program offices with a standard family of MATE with

appropriate standards and specifications. The MATE will be used to support their systems while reducing R&D funds and adverse schedule impacts. A standard MATE family will permit interchangeable modules (hardware and software) to be used at all levels of maintenance. The use of common ATE and common test programs will reduce the problem of units passing tests at one level of maintenance and failing at another level. Accurate and repeatable testing will reduce the excessive cost of sending good components to depot for repair or in the worst case, returning bad items to supply for reissue.

The objectives of the total MATE program are to:

- o Reduce life cycle costs of weapon system support and ATE.

- o Reduce proliferation of ATE.

- o Improve operational utility and test efficiency.

- o Improve ATE management.

The overall MATE program objective will be achieved through an incremental program. The initial segment of the MATE program is the MATE system contract, which will develop and demonstrate the:

- o Design concepts for MATE

- o Design procedures and guides which provide for the consideration of testability in the design of avionics and test equipment systems.

- o Acquisition/application guides for the planning and implementation of avionics systems maintenance support.

In the follow-on increment of the MATE program, a prototype MATE System will be developed, and the evaluation and refinement of the MATE System end-products will continue.

4.3 NATO ATE

The REMUS is an automatic test system program whose objectives are to provide the Federal Republic of Germany armed forces with standardized ATE hardware/software at the general support maintenance level. The REMUS concept calls for computer-controlled ATE composed of standard building block elements to handle the four major functional categories of testing--low frequency analog, digital, high frequency, and microwave. The United Kingdom Royal Navy plans to procure 90 ATEs for use in contractors plants and depots to support several torpedo and missile weapon systems.

5.0 STATUS OF ATE IN THE ARMY

This section is not intended to cover all Army ATE but does address those ATE systems considered of historical or technical interest.

5.1 Depot Installed Multi-Purpose Automatic Test Equipment (DIMATE)

One of the first major Army initiatives into the utilization of ATE was started in the early 1960's, when a program was approved to design and install comprehensive (by standards of that period) automatic test equipment at the three CONUS electronic depots. This system, DIMATE, was designed to perform end-to-end checkout and diagnostic testing of electronic equipment. DIMATE was first installed in 1964 at Tobyhanna Army Depot, with other DIMATES later installed at Sacramento Army Depot and Lexington Blue Grass Army Depot. These systems are still operational, but are considered technically obsolete, and some recent efforts have been initiated toward replacing the DIMATEs.

5.2 General Purpose Automatic Test Equipment (GATE)

DIMATE was followed by another effort to utilize automatic test equipment at two CONUS depots with the installation of GATE configured around a commercial Hewlett-Packard 9500 system. This system, installed in 1970, was designed to test and diagnose the anti-intrusion electronic sensors (antilog) developed by the U.S. Army Mobility/Equipment Research and Development Center. These systems are presently in use at Tobyhanna Army Depot (TOAD) and Sacramento Army Depot (SAAD).

5.3 Digital Automatic Card Tester (DACT)

In 1970, a system called DACT was installed at two (TOAD and SAAD) of the CONUS electronic depots. These digital card testers were installed to provide support to the AUTODIN cards. While the GATE at TOAD is used to support AUTODIN cards in a production mode, the backup GATE at SAAD was subsequently programmed to support some of the DIMATE cards. These General Dynamics-designed units were configured around a Hewlett-Packard 9500 base and consist primarily of off-the-shelf commercial test equipment.

5.4 Depot Multipurpose Automatic Inspection and Diagnostic System (Depot MAIDS)

Another automatic test equipment installed in a CONUS depot was the Depot Multipurpose Automatic Inspection and Diagnostic system (Depot MAIDS). This system, installed at Letterkenny Army Depot (LEAD) in 1971, was intended to provide preteardown inspection, diagnostic evaluations, and fianl run-in for the select tank automotive engines. This system consisted of computer-controlled dynamometer test stands and was programmed to test the AVDS 1790 series engine and some automotive transmissions.

While the concept of Depot MAIDS was never technically refuted, implementation was partially defeated by certain Army depot decisions (i.e., LEAD was not selected for a major tank rebuild program). A major tank rebuild program would have resulted in Depot MAIDS being used more for pre-overhaul testing, where the greatest potential savings would have resulted. Instead, LEAD received engines that were removed from vehicles and returned to the depot. These engines often had been cannibalized without the resulting holes being plugged. Rainwater entry into these engines ensured that overhaul, whether originally needed or not, was required by the time the engine reached the depot.

While Depot MAIDS did not fulfill its potential as a pre-overhaul diagnostic tool, its performance in a role as a final checkout station proved valuable, and a follow-on program to the Depot MAIDS has been proposed. This program includes the installation of computer-controlled dynamometer test stands at Anniston Army Depot (ANAD)

5.5 Army Depot Automatic Diagnostic System (ADADS)

Another Depot ATE is the Army Depot Automatic Diagnostic System (ADADS) designed to test Laser Range Finders (LRF) and the M60A1/A3 Add-On Stabilization systems. Frankford Arsenal proposed to design and build an LRF system in FY'74, with contractual efforts initiated early in FY'75. In 1975, Frankford Arsenal also proposed to modify this system to accomplish testing of the M60 series Add-On Stabilization subsystems.

5.6 Missile Automatic Test Equipment (MATE)

During 1974, the U.S. Army Missile Command experienced problems replenishing the circuit cards for the Improved Hawk. These cards had been designated throwaway, consistent with the maintenance concept of that period. Problems resulted partially because Army logistic planners made assumptions about support parameters that they could not control. In this case, an assumption was made that the circuit card throwaway rate would be equivalent to the card failure rate. This turned out to be inaccurate because in most cases, the Improved Hawk diagnostic procedures only fault-isolated to a group of cards. Another assumption made was that an infinite number of cards could be procured from the contractor for the life cycle of the Hawk system. This was also incorrect since contractors have little incentive to supply circuit cards after production and certainly will not jeopardize current production-line operations to be responsive to a fielded system.

As a result of these and other problems, the Hawk Office contracted for the system contractor to test and return good (incorrectly diagnosed) boards and to rebuild bad boards rather than manufacture new ones. The expense of this alternative, while less than throwaway, led to the U.S. Army Missile Command's obtaining three excess automatic test equipments from the SPRINT program in 1975. These systems, since renamed Missile Automatic Test Equipment (MATE), are basically Hewlett-Packard systems with some Martin Marietta-peculiar instruments and interface circuitry.

5.7 Theatre Readiness Monitoring Facility (TRMF)

Another Depot level ATE that is used with the Improved Hawk is called the Theatre Readiness Monitoring Facility (TRMF). There are presently three of

these systems; one installed in Europe, a second at Red River Army Depot (RRAD), and the third in Korea. These systems are large, fixed-location facilities used to automatically test and recertify the Improved Hawk missile rounds. This missile recertification is performed on a periodic sampled basis. Missile rounds found to be inoperative by this method are also rebuilt by this facility. These facilities are considered Quality Assurance test facilities and are managed by the Directorate for Quality Assurance, HQ DARCOM. These systems were initiated about 1970, and the last unit was installed in Korea in January 1977.

5.8 TOW/COBRA

In 1975, while the U.S. Army Missile Command was processing and renovating the three excess MATES, the TOW/COBRA Project Office was in the process of selecting an ATE system. The U.S. Army Missile Command was requested to standardize its ATE or adopt an existing other major ATE system already in development or in the Army inventory. The eventual decision made was to develop a special TOW/COBRA ATE called Fully Automatic Diagnostic Equipment (FADE) configured around a Hewlett-Packard 9500-based systems. Special ATE capabilities, in addition to those required for TOW/COBRA, were also contracted for. These features included a computer-generated stimuli subsystem and a sampled measurement subsystem. The reason provided for adding the additional capabilities was to develop a state-of-the-art ATE system to satisfy other MICOM ATE requirements and be consistent with the ATSS Program. The TOW/COBRA Project Office also decided to develop a government-owned ATLAS compiler for their ATE system. The decision to contract for this ATE system in lieu of adopting an existing system was based on the extremely tight developmental schedule for the TOW/COBRA.

5.9 Land Combat Support System (LCSS)

Only a relatively small number of ATE systems have been developed for use in the field Army environment. The largest field Army ATE investment is represented by the Land Combat Support System (LCCS). The system was initiated in 1964, with fielding beginning in 1967. The U.S. Army Missile Command decided to develop a single ATE system to support four separate land combat missile systems. Systems supported by the LCSS are the SHILLELAGH, TOW,

LANCE, and DRAGON. The LCSS was attacked by skeptics during its development and critized afterward by users because of numerous technical, supply, and training problems. While some of the critism of LCSS was justifiable, other LCSS criticism actually reflected shortcoming of the planning efforts. For example, a shortage of the MOS 27B personnel required to operate the LCSS impacted the overall efficiency of this system. Problems keeping repair parts also caused low availability for the LCSS. Both examples demonstrate pitfalls inherent in assuming optimistic values for support parameters beyond the control of the concept planner. Irrespective of problems experienced by the LCSS program, it did demonstrate that general purpose ATE could be developed to support several systems and that the ATE could operate in a field environment. Presently, there are 44 LCSS in the Army inventory and there are no plans to field additional systems. Several product improvement programs (PIPs) have been propsed to LCSS to upgrade these aging systems. These PIPs range from component replacement to reconfiguration of LCSS into a single van.

The LCSS provides a high-speed automatic test facility and a repair facility for Direct Support (DS) and General Support (GS) to the SHILLELAGH, LANCE, TOW, and DRAGON missile systems. The system consists of three major equipments.

The Guided Missile System Test Station is a digital-controlled automatic electronic test set. It consists of rack-mounted power, stimuli, switching, measuring, optical equipment, and a clean booth. Digital control of the system is accomplished by a perforated tape or, under certain maintenance operations, a manual keyboard. The unit can make static and dynamic self-tests of its control, switching, stimuli, and measuring equipment. It is fault-isolated by continuous monitoring devices and programmed self-tests. The test set is designed for transportation in combat areas on standard military wheeled vehicles, by fixed wing aircraft, by rail, by ship, and by landing craft. Skids, towing eyes, and lifting eyes are provided on the shelter structure.

Guided Missile System Shop Equipment is commonly known as the repair and storage group. It is a shelter-housed manual test, repair, and storage unit for supplementing the maintenance and repair facilities of the test station.

The engine generator set is a trailer-mounted, liquid-cooled diesel generator that provides 45 kW of power at 120/208 volts and 400 Hz.

The test station uses two levels of taped programs--a system self-test program and individual LCSS UUT programs. Specifically designed taped programs or manual test procedures are used to test and fault-isolate UUTs. Assemblies essential to the automatic operation are tested in the system (in rack). Those not essential to the automatic operation are tested on the bench (removed from the system). For tape tested items a programmed series of tests are performed, and the printer prints instructions to aid the operator in conducting the program. When a malfunction is detected in a UUT, these printed instructions guide the operator with proper corrective action. When manual test or repair procedures are required, the printed instructions direct the operator to UUT fault-isolation and repair instructions. For non-tape tested items, the technical manuals contains the manual tests and fault-isolation procedures necessary to correct the fault. Repair procedures are also provided.

5.10 Electronic Quality Assurance Test Equipment (EQUATE)

The effort on the Electronics Quality Assurance Automatic Test Equipment, designated AN/USM-410, dates back to the early 1960's when the U.S. Army Electronics Command (ECOM) proposed to develop standard automatic test equipment to be used as factory production-line Special Acceptance and Inspection Equipment (SAIE) for electronic equipment. Subsequent to this effort, a proposal was made in 1966 to develop a field version of this equipment for a Computer-Controlled Automatic Test Equipment (CATE). In 1969, due to problems encountered during manufacturing testing of several radios, a technology program was initiated at ECOM to develop an array of test equipment to facilitate factory testing. This effort resulted in the development of a Special Acceptance Test Equipment (SATE).

Many factors prevented the formal approval of a CATE requirement. However, ECOM continued their EQUATE contractual effort and produced their first EQUATE in 1973. The overall characteristics of the system are based upon third generation technology; i.e., maximum use of the computational capability of

the central processor to reduce hardware size and limited power requirements for tactical portability. It has full analog and digital capability from DC to 18 GHz and is modular with respect to both hardware and software. It is modular with respect to stimuli and measurement as a function of frequency. There is a separate microwave rack to cover the 500 MHz to 18 GHz range, where required, and a programmable interface unit (PIU) with 128 fully programmable pins, each of which can be connected to any stimuli or measurement function. The PIU is required primarily for heavy digital workloads. EQUATE uses an adapted ATLAS as the test programming language with a FORTRAN intermediate code, and program generation and validation can be undertaken directly on the test station.

The initial military feasibility of tactical ATE was demonstrated at Project MASSTER, Fort Hood, Texas, May-December 1975, utilizing serial number 1 mounted in a semitrailer van. The test was highly successful and demonstrated many advantages over manual testing methods with respect to test time, reproducibility of test results, and improved mean-time-between-repairs. It also indicated that current maintenance personnel could be trained to perform these functions.

In the Army during the past decade, the interest and need for automatic test equipment has continued to grow due to the increasing number of new communication-electronics systems being developed which were dependent upon computer control for their operation. Independent analyses confirmed that the only viable way to maintain these systems in the field was by the use of an automatic test system of at least equal capabilities. Further, TRADOC established a policy that all new weapons systems undergoing operational and developmental tests should be supported with the same complement of test equipment which will subsequently be used in the field. To date, deployment has been at Army depots or contractor's installations for the development of test programs or demonstration of field maintenance concepts.

The Department of the Army has made a recent decision that the field support requirements for EW-SIGINT systems are urgent and has directed that an engineering development program be undertaken to provide the ruggedization

of the AN/USM-410, which was initially designed as a factory type equipment. Some additional ruggedization will be required with respect to the mechanical rigidity of the racks, drawers, printed circuit boards, card connectors, and retainers. Consideration is also given to provide improved circuit protection against water condensate and to:

- Provide a full self-test capability to simplify logistics support.

- Expand capability and flexibility of the system to make it more adaptable to some of the future requirements.

- Improve modularity and human engineering of the rack arrangement.

The overall goal is to have available in the field, in the 1983 time-frame, a tactical ATE system compatible with the general support requirements of new weapons systems which will be introduced into the inventory within that time. However, it should be noted that each AN/USM-410 is expensive and, to date, only limited numbers have been procured.

The system referred to as GS/ATSS (General Support/Automatic Test Support System) consists of Automatic Test Equipment AN/USM-410 and the Electronic Repair Facility (ERF).

The test station, consisting of four cabinets and rack assembly, is fully automatic and uses the IEEE internal bus and an ATLAS compiler. Test program storage is on magnetic tape, punch tape, and/or disk storage. Controller peripherals include:

Data Recorder

Line Printer

Tape Reader

Display Terminal

Keyboard

Disk Storage

Card Reader

Compiler

Magnetic Tape

Calibration tests are controlled by the computer. Test station features include test repeatability, self-test capability and unit under test (UUT) fault isolation. The stimulus sources are:

Pulse Generator (programmable)

Function Generator (programmable)

Synchro Stimulus

RF Source A (programmable in steps of 100 Hz, 1 kHz, 10 kHz, 20 kHz, and 40 kHz)

Fixed AC Power Supply

DC Power Supply (programmable and fixed)

6.0 ARMY MISSILE SYSTEMS

Missile systems have been one of the first users of tactical ATE due to their high volume, complexity, and the premium placed on their operational readiness. This section briefly describes several such systems. The Land Combat Support System (LCSS) is discussed in Section 5.0 (paragraph 5.9).

6.1 U.S. Roland

The U.S. Roland is an all-weather, short-range air defense system currently being manufactured in France, Germany, and the United States. The system was jointly developed by France and Germany. Hughes Aircraft Company and Boeing Aerospace Corporation are co-licensees for production of Roland in the United States for the U.S. Army. The weapon system uses a command-to-line-of-sight missile. The Fire Unit is designed to be self-contained and includes a surveillance radar with IFF; optical, infrared and radar trackers; an RF command data link between command computer and missile; and necessary hydraulic, environmental control, electrical power, and communications equipment. The

present DOD program involves the transfer of technology, fabrication, and testing of fire units built in this country. Each country is developing its own Field Maintenance Test Equipment.

From late 1974 to early 1976, the U.S. Roland Program had planned to utilize European test equipment. It eventually became evident that the European test equipment design was not as mature as had been believed by the U.S. Army. In addition, the Europeans, in 1975, began considering changing their field maintenance test set (FMTS). This action would have made the U.S. Army the only user of the original European Roland field test equipment. After the requirement to select other test equipment became known, requests were made to the Roland Project Office to consider adapting one of the existing ATE systems. Schedule constraints prevented this, however, and the Roland PM contracted for development of a Hughes-designed, Hewlett-Packard 9500-based system in October 1967.

The support concept for U.S. Roland is: at the organizational level, faults within the Fire Unit are isolated to the defective assembly, or black box level, the effective box is replaced, and the Fire Unit is restored to operation. The defective box, removed at the organizational level, is returned to the Direct Support Unit for repair. At the Direct Support Unit the box is tested and repaired, generally by removal and replacement of the defective module; for example, a printed circuit card. The Direct Support Unit then verifies proper operation and returns the repaired box to the spares pool. The removed module will then be repaired at the most cost effective location, either General Support Unit or Depot. The equipment used for Direct Support Maintenance of U.S. Roland is the Field Maintenance Test Set (FMTS).

The Field Maintenance Test Set includes two electronic maintenance vans, a hydraulic maintenance shelter and three standard trailer mounted Army generators, towed by standard 2 1/2 ton Army trucks, which also transport the associated mechanical tools and fixtures. Two electronic maintenance vans are required: an RF Van and a Low Frequency Van. Identical "core" automatic test equipment hardware is used in the test stations in both vans.

DOD has minimized development risk by utilizing factory automatic test facility hardware and software as the basic building block for the Field Maintenance Test Set. Development cost has also been minimized by utilizing proven off-the-shelf hardware and software which is commercially available. Schedule risk has been lowered by utilizing the ARINC ATLAS 416-11 language for applications test programs along with the Hewlett-Packard ATLAS Compiler. Software is the critical item from a schedule viewpoint. Growth capability has been maximized by providing for measurement and stimuli in the basic test stations to enable expansion of the test capability by only adding computer software programs and interface adapters peculiar to each additional unit to be tested.

A DARCOM workload analysis has indicated that two independent computer-controlled test stations are required: an RF Station and Low Frequency Station. The system is based upon commercially available automatic test equipment supplemented by U.S. Roland specially designed items, assembled in racks and environmentally protected by a standard Army van. Specially designed equipment will use high-reliability, MIL standard parts or equivalent. The FMTS test capability will be expanded at a later date to provide for testing of organizational maintenance test equpment, training equipment, and other U.S. Roland hardware as necessary and cost effective.

The FMTS design uses the Hewlett-Packard 9580 Test System as the common "core" for the field test stations and the factory test equipment. This "common core" approach, in turn, uses the IEEE Standard 488 interface bus, the Hewlett-Packard 2113A solid-state-memory computer, the Hewlett-Packard improved modular switching subsystem, and the Hewlett-Packard real-time executive software and ATLAS compiler. The FMTS design approach makes maximum use of standard commercial instrumentation, assures maximum commonality of physical hardware design, uses a common shelter installation and environmental protection design, and has taken advantage of commonality with factory test equipment.

The first Hewlett-Packard 9580 Automatic Test Station was installed at Boeing's Seattle plant in 1975. Software programs and interface adapters are being developed, and the test set is being used to check out several of the

Roland assemblies and subassemblies at the present time. The software design uses:

- o Existing off-the-shelf software to the maximum extent.
- o Hewlett-Packard's RTE III Operating System to control and monitor test station operation.
- o The Hewlett-Packard ATLAS Compiler to compile ATLAS application programs and generate ATS BASIC test programs.
- o The ATS BASIC software to execute test programs by call-up of instrument drivers.
- o Hewlett-Packard instrument drivers for control of the switching, stimuli, and measurement equipment within each of the test stations.

Software which must be developed consists of application programs, self-test and calibration programs, and instrument drivers. The application programs are written in ARINC 416-11 ATLAS as procedures and diagnostics for test of FMTS testable units. Self-test and calibration programs are also contractor-developed and are written in ARINC 416-11 ATLAS as procedures and diagnostics for test and calibration of the test stations themselves. Instrument drivers are assembly language programs developed for control of non Hewlett-Packard instruments in the test stations.

Hughes Aircraft is developing the Low Frequency Test Station. With the exception of the prime power control panel, the entire test station is made up of commercial instruments mounted in commercial ruggedized racks. The panels for the RF test station are also being designed by Hughes and the rest are commercial instruments. Two panels are being developed for interfacing with the Roland Track Radar and Command Transmitter units. They provide RF low-power signal conditioning, RF switching, and RF high-power loads. Two panels are also being developed for interfacing with the Roland Surveillance Radar units for RF low-power signal conditioning, RF switching and RF high-power loads. Panels are also being developed for spectral noise measurements,

high current switching functions, application of 3-phase power to the unit under test, and test station power control. A load bank is being developed to provide high-power dc loads to test the Surveillance and Track Radar Power Supplies.

6.2 Improved Hawk

The Improved Hawk System is the Army's primary low and medium altitude air defense system. It is used in Corps areas as well as for defenses of air bases and rear logistical complexes. The Improved Hawk increases the range, accuracy, and capability of the older Hawk system. Improvement has also been made on the ground support equipment which is an integral part of the system.

One of the major advances of the Improved Hawk System has been the incorporation of built-in-test equipment (BITE) for the high powered illuminator radar part of the Improved Hawk System. The Hewlett-Packard built-in-test-equipment (BITE) was developed to thoroughly check the radar and perform the required weekly and daily checks for the system as fast as possible, with as few personnel as possible, and with a minimum of external test equipment.

With the built-in-test equipment approach, the daily tests were reduced from 40 to 30 minutes and the weekly tests from 6 1/2 hours to 2 1/2 hours.

Most of the tests performed for the Improved Hawk System are based on introducing a simulated target to the radar (radio frequency test target generator). The simulation can be varied to include various velocities, ranges, and target motions. This simulation approach means that the system can be thoroughly tested and checked out without actually firing a missile.

Other tests for the transmitter, receiver, and radar set groups are provided by other built-in test equipment.

In order to ease the repair of the equipment in the field, "throwaway modules" were used. This means that replacement can be made in the field by replacing a defective module with a new good module.

The Improved Hawk BITE actually consists of building blocks of specialized functional test equipment.

As part of the Improved Hawk Program, the Theatre Readiness Monitoring Equipment (TRME) was developed. This equipment is identical to the equipment used in the factory for acceptance of the Improved Hawk missile. The primary objective of the TRME is to obtain the most meaningful measure of possible degradation in missile readiness due to deployment of the missile in the field. Degradation may be caused by aging, the environment, handling, etc.

The TRME is made up of a number of integrated missile test sets. Missiles are selected from discrete lots in the field for testing. The TRME automatically tests each missile by performing specific missile functions and responses to input stimuli. These responses are compared to how the missile should respond based on predetermined acceptable tolerances. The key characteristic which is looked for is the guidance accuracy of the missile. This is automatically computed based on the responses to the inputs indicated above. The output of the TRME is a punched paper tape which gives the test data of a missile under test. Data is stored so that the data of each missile tested can be retrieved and analyzed if required.

6.3 Patriot

The Patriot, an air defense system, is being developed to replace both the Nike-Hercules and the Improved Hawk in order to provide improved performance to counter the 1980's threat and to reduce the high operating and support costs of the current systems.

The primary benefit of the Patriot System is the low support costs. It is estimated that deployment of the Patriot will decrease the field Army manpower requirements by at least 7,000 personnel. The system has a definitive set of life-cycle goals: less equipment, less maintenance, fewer system peculiar line items, and fewer support personnel than the existing systems. Current estimates indicate the total life-cycle cost to be approximately 50 percent of an equally effective (i.e., comparable firepower) deployment of Improved Hawks.

The maintenance concepts which were defined by the Army to help achieve these life-cycle goals were:

- o Maximum maintenance by operators and crewmen.

- o Extensive use of built-in-test.

- o Maximum use of plug-in assemblies.

- o Minimum number of Battery Replaceable Units (BRUs).

- o On-board spares.

Based on these maintenance concepts, an array of quantitative requirements was defined for Patriot. The quantitative BITE requirements were stated as follows:

Fault Detection:

- o NLT (not less than) 90 percent detected by operators using BITE.

- o Remainder detected by system mechanics using common portable test equipment.

Fault Localization:

- o NLT 75 percent localized by operators using BITE.

- o Remainder localized by system mechanics using BITE or common portable test equipment.

7.0 PLANNED ARMY ACTIVITY

7.1 Direct Support Automatic Test Support System (DS ATSS)

In early November 1979, the Communications R&D Command (CORADCOM) at Fort Monmouth, New Jersey advertised for R&D sources for the development of a Direct Support Diagnostic Test Support System. The advanced development

contract award is scheduled for December 1980. The objective of the program is to develop, fabricate, and field a DS ATSS which has the capability to support a variety of Army systems such as missiles, vehicles, aviation, command and control, and communications.

The system will be used at the Direct Support level to (1) perform controlled tests to detect and isolate facility Line Replaceable Units (LRUs), (2) on-site to supplement BITE, and (3) perform fault verification of replaced units returned to the DS base shop for repair.

The following description of the system was provided in the Commerce Business Daily announcement: The DS ATSS shall be an automated test system and shall provide forward area testing capability for all types of electronic equipment. As an automated system, the DS ATSS shall utilize modern computer technology to generate and route stimuli signals, process and analyze response signals, utilize flexible efficient software and control overall system operations. The design of the test system shall be based on a bus-structured architecture to support distributed intelligence/processing and to achieve a modular construction capability to accommodate specific utilization requirements and types of testing for Direct Support contact team and base shop operations. The test capability utilized for contact team operations shall be a subset of the DS base shop test capability. The major functional areas comprising the DS ATSS shall be: a portable reconfigurable contact test set, a base shop test station, and a complement of plug-in modules. In addition, the program requires the development of a compiler and ancillary software development. In view of the urgent fielding requirement of this test system, the intent is to purchase complete PEP and ILS support.

The planned acquisition of the DS ATSS is to fulfill the requirements specified in a DARCOM/TRADOC LOA for the investigation of a family of Automatic Test Support Systems. The system will be operational approximately late 1985.

The Draft Mission Element Need Statement (MENS) describes the ATSS family concept as a family of automatic test equipment for use at Organizational, Direct Support (DS), and General Support (GS) maintenance levels. This family

would be standardized to a maximum extent possible. It is envisioned that various ATSS test configurations will reflect tailored test sets that utilize a common core, a standard programming language, standard interface bus, and minimum essential commodity peculiar hardware and applications software. The various members of the ATSS family will be capable of automatic self-test and maintenance calibration plus provide an automatic test capability for replaceable units (RU), i.e., assemblies, modules, printed circuit boards, irrespective of their end-item commodity. Accordingly, the various ATSS configurations will verify their own correct operation and diagnose failures in RU in order to enable return to service of items from missile, aviation, communications-electronics, wheeled vehicle, and combat vehicle systems. Large scale ATE will normally be utilized at the GS maintenance echelon, and small scale, simplified ATE will be employed at organizational and direct support maintenance levels. Since software is the main cost driver, it is envisioned that all configurations of the ATSS family will use various adaptations of the same applications programs with the lowest echelon consisting mainly of simple go/no-go capability, and with increased sophistication of programs at the higher echelons.

The MENS further defines General Support, Direct Support, and Organizational Maintenance under the ATSS concept.

Maintenance operations at the GS level will involve test and repair of RUs and PCBs at the commodity support battalions and test and repair of all types of Army PCBs at a PCB Repair Cell/Section of a Communications-Electronics Materiel Support Battalion. This facility is non-commodity oriented and will handle all repairs requiring component replacement, e.g., replacement of a chip on a PCB, regardless of the supported system(s) from which they came. The GS/ATE will be used at this facility for diagnostic testing and then verification that the correct repair was made. The major workload at all other commodity support battalions will consist largely of repairing faulty assemblies and subassemblies by replacement of PCBs or modules. As more systems are fielded, the repair of RU(s) will represent the primary workload at each of the GS commodity battalions. Early indications are that PCBs and modules from all sources can be better and more efficiently tested

and repaired at a common facility as soon as the workload becomes high enough to economically justify consolidation.

With the availability of ATE at the GS level, it is expected that the DS maintenance function for many supported systems would be largely eliminated. Exceptions will be special situations concerning support to small missiles and other systems that occur in large numbers such as tactical radios, aircraft, and vehicles. Supported items such as these should also be designed for simplified and rapid testability by the use of suitcase-type automatic test equipment identified as DS/ATE. Here again, fault isolation and diagnosis at DS should be to the RU which should possess design features for rapid access, removal and replacement. The faulty RU would then be sent from here through normal channels to the appropriate commodity GS battalion for repair and reissue.

At the Organizational level, with the supported systems designed for maximum built in testability, fault diagnosis will also be by utilization of "suitcase" test equipment hereinafter called OATE. The tailored OATE configurations will require built in/on test connector(s) for rapid connection to the supported systems and subsequent diagnosis and fault location. OATE will be utilized initially to assist and eventually replace manual subjective means for restoring supported items to operational use. OATE will perform go/no-go routines on suspected faulty items while still part of the system (on-line) to confirm malfunctions detected by other means such as BITE.

8.0 BUILT-IN TEST EQUIPMENT (BITE)

The basic division in automatic test equipment is on-line test and off-line test. The on-line test functions are actaully a part of the weapon system and include Built-In Test (BIT) and Build-In Test Equipment (BITE). The off-line test functions are external to the basic weapon system and can exist at various maintenance echelons.

The Army's ATSS concept envisions that BITE will be used at the organizational level to determine the faulty line replaceable unit. According to

Major General Dickinson*, "many of the future Army weapon systems will have a great deal of BIT which will isolate faults with a 95 percent probability of achieving a correct diagnosis".

When determining whether or not BIT/BITE should be used, it is usually agreed that BIT/BITE is not a substitute for inherent reliability of the system and that BITE must be more reliable than the system into which it is incorporated.

8.1 Test Requirements

The recent Industry/Joint Services Task Force reported that under the maintainability requirement for a weapon system, self-test or BIT has been specified but many times independent of the external automatic test system required to support the system in the field. It is interesting to note that within the Army's concept for a family of ATE, referred to as ATSS, the Depot/Factory test requirements are not specifically addressed. It should be noted, however, that the design of any test equipment, either on-line or off-line, must take into consideration the depot/factory test requirements. Continuity must exist in test requirements between the different echelons of maintenance. To do otherwise can result in inconsistent test results for identical RUs.

8.2 Test Effectiveness

Testability is a subset of maintainability and represents the ability to measure or verify acceptable system performance, detect critical faults, and provide adequate fault isolation. Although maintainability requirements have existed for many years in systems and equipment acquisition specifications, the desired level of testability performance commensurate with weapon systems readiness and cost targets has not been achieved.

BIT, an on-line test function, as currently realized in modern weapon systems, is not as effective as it should be. An unacceptably high false alarm

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*Major General H. Dickinson, Commander, U.S. Army Communications Research and Development Command in a speech at the Automatic Test Conference and Workshop in San Diego, California, April 1978.

rate has been exhibited which minimizes the usefulness of the weapon system and creates an ambiguous system operational status. This leads to an inordinate "false removal" rate and tends to unnecessarily load the intermediate shop.

As the technology content in end-item systems advances, so will that required for BIT implemented in both hardware and software. A measure of effectiveness of testability is missing; it has been more qualitative than quantitative. In the majority of systems deployed today, insufficient technical coordination and interface compatibility has been effected between the on-board BIT and the off-line external ATE required to test the same systems at the intermediate maintenance level.

The effectiveness of the ATS, or off-line test function, is directly proportional to the development maturity of the weapon system to be supported when concurrent development of both systems occurs. Changes to the weapon system cause changes to the ATS, and coupled with the normal cost and schedule allocations for support equipment, the effectiveness quotient of the ATS diminishes.

Another area determined to be of significant negative impact is the test envelope link between all maintenance/test echelons, and perhaps between factory and field sites. For the most part, end-item equipment has been tested differently and with different test systems at the various support levels and contractor's production environment. This factor makes it extremely difficult to correlate test failure history between sites and apply it effectively and timely to accelerate field maturity. The reverse flow has also been observed. Field failures impeding readiness are not easily correlatable nor resolved in a timely manner when test systems and methods are dissimilar. A consequence of this has been congested logistics pipelines stuffed with high value assets, a good deal of which are properly functioning units. This unnecessarily drives the cost of spares higher with no appreciable increase in system readiness.

Similar to other technical disciplines (e.g., Reliability) in the past which required a boost in authority to influence the final system design and performance, Testability has emerged as a significant factor requiring critical recognition. This one key discipline has a high degree of inter-dependency between end-item system performance and system support in the field.

Recent trends to weapon system acquisition have favored economic incentives for Reliability and Maintainability performance during the system development process. This appears to be moving in the right direction, but increased focus on Testability as a significant management consideration is still required.

8.3 BIT/BITE Effectiveness

The recent Industry/Joint Services Task Force reported that the technical shortfall of BIT is of concern. For any weapon system, BIT must be considered mandatory and represents a significant human factors element between the operator and his complex machine. All too often BIT is regarded as a simple GO/NO-GO function -- not realizing the challenge for effective design of this peripheral test function as an integral part of the weapon system.

Some of the salient technical factors evaluated as the cause for unsatisfactory BIT performance are as follows:

- Insufficient standardization of testability terms and definitions. Too often qualitative rather than quantitative parameters are imposed which defy verification.

- Figures of merit for acceptable BIT performance are deceptive; only extensive test and verification of primary fault modes can yield the confidence level desired. This is costly and impractical due to the extensive profile that maintainability demonstrations entail, coupled with the lack of test maturity that can only be experienced in the initial deployment phase.

With the prior knowledge that electronic subsystems will be supported on ATE in the field, a stronger coupling of BIT design to the external ATE characteristics is necessary. The discipline of their interface design has not been enforced sufficiently, and in some cases, the need may not be recognized.

8.4 Air Force Experience With BIT

During the past 10 years the Air Force has experienced a phenomenal growth in complexity of its weapon systems, primarily the avionics equipment. In order to support these complex systems, and be cost effective, automatic Fault Detection and Isolation (FDI)* systems have been introduced. This has been accomplished primarily through the use of BIT and FIT equipment. During Operational Testing, the Air Force Test and Evaluation Centers experience has shown that BIT and FIT systems fall far short of their expected performance. Instead of an aid in supporting complex systems, they have proven to be less reliable and more troublesome than the systems they support.

One problem the Air Force has experienced is that the FDI systems are either very immature or nonexistent during the Operational Test and Evaluation (OT&E) phase. The reason for this has been the very low priority placed on test systems by the contractors during development. Contractors usually depend on very highly skilled technicians during the Operational Test and Evaluation phase rather than use FDI systems and a skill level equivalent to that used by the Air Force.

Poor reliability of FDI systems has been a common problem which results in very high false alarm rates. On one aircraft, they experienced 1800 failures in mission hardware as indicated by BITE; however, only 75 were true failures.

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*The Air Force uses FDI as a generic term that encompasses the following:

BIT - Built-In Test
BITE - Built-In Test Equipment
FIT - Fault Isolation Test
SIT - System Integration Test
ATE - Automatic Test Equipment

Other experience during OT&E testing has shown an interface problem between the aircraft BIT/FIT systems and ground ATE. This problem is primarily due to the low priority assigned to both BIT/FIT and ATE.

One recommendation the Air Force has made based on their experience is that FDI components such as BIT, FIT, ATE, etc., be treated as a total system with the equipment it is supporting and that both test equipment and the mission hardware be developed simultaneously.

On another Fault Detection System, the Air Force has had considerable success. This system, the Central Integrated Test System (CITS), was developed for the B-1 aircraft and has proven to be very successful. The CITS provides on-aircraft information relative to the "health" of the aircraft subsystems by continuously monitoring all aircraft subsystems in flight and on the ground. The system displays and records failed modes of operation and fault isolates to the LRU level.

It has been proven that considerable time was saved by using the CITS to perform pre-flight and post-flight testing. The logistics analysis of the on-board test system indicates that there has been a substantial savings on support costs. These savings include reduction in maintenance personnel, reduced operational support equipment, lower skill levels, reduced quantities of spares, and a reduction in maintenance man-hours to flight hours.

Of prime importance in using the CITS concept is getting the system into use by field test personnel as quickly as possible during the flight test program. This allows interface problems to be identified and corrected while the subsystems are still in the development stage. During the flight test program, equal importance for test and troubleshooting time must be given the on-board test system as any other major on-board system. Without this consideration, on-board test system hardware/software development will be lagging, and test results will not be available to evaluate the effectiveness of the on-board test system.

As a test system of the late 1970's, the CITS uses the latest technology and techniques and offers a significant future potential application to other aircraft, both existing and planned.

8.5 Design for Testability

Design for testability is a systematic controlled process for incorporating testability characteristics into the basic system design. A successful design for the testability program must include timely specifications, identified measurement techniques, and effective evaluation methods. Specifications for testability must be written concurrent with those for the system design. Testability features should be demonstrated during the full-scale development phase.

A design for the testability program should be incorporated as an integral part of the System Engineering and Design Engineering effort. Testability considerations such as ATE compatibility, BIT hardware, diagnostic software, and performance monitoring circuits can be incorporated as part of the basic design.

8.6 BIT on the Patriot Weapon System

An example of extensive use of BIT in an Army missile system is the Patriot Weapon System. The maintenance concept defined by the Army for this system included extensive use of BIT and the maximum use of plug-in assemblies. Based on the maintenance concept defined, the following BITE requirements were established.

- Fault Detection. Not less than 98 percent detection by the operator using BITE.

- Fault Localization. Not less than 75 percent localized by the operator using BITE.

To satisfy the BITE system requirements, a BITE system concept was developed. The basic features included:

- Sensor points located throughout all equipments.

- Collection and formatting of status data.

- Reporting to the central computer or BITE panel.

- Analysis conducted by computer.

- Simplified output to operator.
  - Which test failed.
  - BRU(s) suspected (name, location, and part number).
  - Manual procedure reference, if required.

- Test for repair verification.

There were four essential steps in the BITE system development process, starting with paper design, and ending with the assessment of the BITE system over a substantial period of time. These four steps are as follows:

- Maintenance Design Disclosure. The Maintenance Design Disclosure (MDD) is a key item in the BITE development program. Each MDD contained the data needed for maintenance of a particular subsystem within the weapon system.

- BITE Analysis. The primary purpose of BITE analysis is to verify that the requirements for fault detection and fault localization are satisfied. Other objectives are to optimize the order of RUs in each replacement sequence so that MTTR is minimized, and to develop a data base for use in maintenance and logistic analyses.

- BITE Checkout. The performance of the BITE software is verified during integration of the tactical systems. Each test of the status monitor program, which performs on-line fault detection, and of the diagnostic program, which performs off-line fault localization, is checked out to ensure that it functions as intended.

- BITE Assessment. The operation of BITE is measured quantitatively for each system throughout its performance test program. Each relevant failure is scored to determine if BITE functioned as intended for

both fault detection and fault localization. If it did, then the predictions made during the BITE analysis phase are valid. If it did not, an investigation request is issued to identify the source of the discrepancy and to determine the proper corrective action. Both hardware and software changes are being made as a result of these investigations.

The assessment data collected to date show that 99.2 percent of all faults were detected by BITE, which exceeded the requirement of 98 percent.

In conclusion, the Patriot maintenance concept is that an operator with relatively limited maintenance skills is able to detect and localize most faults. This requirement has been approached by providing a BITE system. Assessment to date indicated that the BITE is performing as required. The success of BITE in meeting the requirements is the direct results of incorporating BITE requirements and BITE during the weapon system design phase.

9.0 TEST REQUIREMENTS ANALYSIS

An evaluation of MICOM missile systems was accomplished for the purpose of identifying those systems for subsequent development of Test Requirements Analysis (TRA). The following categories of missile systems and the missiles within each category were evaluated.

a. <u>Air Defense</u>

- o Chaparral
- o Hawk
- o Hercules
- o Patriot
- o Redeye
- o Stinger
- o U.S. Roland

b. <u>Surface-to-Surface</u>

- o Copperhead
- o MLRS (GSRS)
- o Lance
- o Pershing II

c. <u>Anti-Armor</u>

- o Dragon
- o Hellfire
- o LAW
- o Shillelagh
- o TOW
- o Viper
- o 2.75 Rocket

Within the three categories, the following missile systems are recommended as candidates for performing a TRA.

a. <u>Air Defense</u>

- o U.S. Roland
- o Patriot

b. <u>Surface-to-Surface</u>

- o MLRS (GSRS)
- o Pershing II

c. <u>Anti-Armor</u>

- o TOW
- o Viper

Of the six candidate systems, the first system within each category will be selected for performing the TRA. Should any problem develop in using that system such as unavailability of data, the second system identified will be used for analysis.

A major consideration in selecting the above systems is the potential for influencing the design of the Automatic Test Equipment that would be common to more than one of these systems. Obviously, those systems still in the development phase offer the best potential for adapting a common Automatic Test Equipment Missile System (ATEMS).

The following outlines areas of investigation required for the TRA effort:

- Maintenance concept
- Test concept
- System criteria and goals
- Corrective maintenance time goals
- Availability requirements
- Reliability requirements
- Performance specifications
- Failure mode and effect analysis (FMEA)
- System block diagrams
  - Functional
  - Signal Flow
- Test requirements by levels of maintenance
- Commonality of test requirements between levels of maintenance
- Calibration requirements
- Acceptance test requirements

- Parameters to be tested
  - Digital
  - Analog
- Logistics support analysis (LSA)
- Stimuli required in testing
- Skill level of maintenance personnel (MOS)
- Manning level of maintenance personnel
- Test points
- Trade studies
- System software
- System and test tolerances
- Documentation defining configuration
  - System specifications
  - Changes
- Environmental conditions
- Physical characteristics
- Safety considerations
  - High voltage/current
  - Radiation
  - High Pressure
  - Explosives

BIBLIOGRAPHY

1. Report of Industry Ad Hoc Automatic Test Equipment Project for the Navy

Vol I: Executive Summary

Vol II: Research Development, Test, and Evaluation: Conclusions and Recommendations

Vol III: Management Considerations: Conclusions and Recommendations

Prepared by:

Aerospace Industries Association
Electronic Industries Association
National Security Industrial Association
Western Electronics Manufacturer Association
Shipbuilders Council of America

April 1977

Abstract

This report was prepared by a group of 174 technical and management experts representing manufacturers of aircraft, electronics, test equipment, and computers, as well as members of the academic community. It treats all aspects of future automatic testing of Naval weapon systems and equipment, for the years 1981 through 1985.

U.S. Navy concern with logistic costs and with operational readiness is the fundamental frame of reference for the efforts performed on this Project. This Report presents conclusions and recommendations relative to all aspects of automatic testing that bear upon these factors.

To the degree that these recommendations can be successfully implemented, the future cost-effectiveness and operational efficiency of automatic testing will be materially enhanced, resulting in improved fleet readiness at an affordable cost.

2. The Army Task Force Report on Automatic Test Support Systems - ATSS

Product Manager for Automatic Test Support Systems

May 1978

Report No. AD-A061756
AD-C016067 (Classified and Limited Version)

Abstract

Under general guidance from DARCOM, the Army task force assesses the current Army Automatic Test Equipment (ATE) posture and develops an optimum ATE acquisition strategy for this future. The Task Force investigated the technical feasibility, employment concepts, and operational desirability of developing a family of Automatic Test Support Systems to be used for the maintenance of Army material. This included formulation of interim and long-range ATE approaches for major subordinate commands and program managers and a plan for future ATE development and acquisition.

3. Metrology for Future Army Test, Measurement, and Diagnostic Equipment (TMDE) Requirements

Booz-Allen Applied Research for
U.S. Army Electronic Command

June 1977

Report No.: AD-A041109
ECOM-76-1387-F

Abstract

During the past decade, both the capabilities and technology of Army communications-electronics (C-E) equipment have rapidly advanced. The objective of this study was to forecast the impact of future technology and design trends on the TMDE equipment for the 1985-2000 time frame. The TMDE would be required to support fielded Army C-E equipment. It is anticipated that this forecasted impact can influence current and future Army equipment development programs so that any equipment needed to maintain the prime equipment items would be available when the prime equipment is fielded. This program will provide specific recommendations concerning measurement requirements and test techniques necessary to support future Army C-E systems and subsystems.

4. Operational Test I of General Support/Automatic Test Support System (GS/ATSS)

U. S. Army Air Defense Board

November 1978

Report No.: AD-B032098
8-OTN 452

Abstract

The GS/ATSS is considered to be effective in diagnostic testing, fault isolation and repair of printed circuit boards such as those found in the AN/TSQ-73. The effectiveness of the ATSS to perform diagnostic testing, fault isolation and repair of FM radio modules could not be adequately assessed due to the numerous software program failures and the lack of repair parts. The system could perform functional and diagnostic testing on FM radios; however, it was considered time consuming and, in some cases, the time exceeded that required using the current manual method. The ATE was considered effective in performing quality assurance checks on FM radios. The Equipment Repair Facility was effective in the repair of modules and printed circuit boards, however, it was not used to repair radios as they were repaired on-line during testing with the ATE.

5. Automatic Test Equipment - Special Report

Electronic Engineering Times

January 7, 1980

6. Intelligent Strategy with Distributed Database for High-Volume LSI Testing

Chao S. Chi - Sperry Research Center

IEEE Transactions on Instrumentation and Measurement, Vol. IM-27, No. 2, June 1978

Abstract

As semiconductor technology has matured, the advent of LSI chips such as microprocessors with substantially increased device functionality and complexity has created unparalleled challenges to test philosophy. Most traditional screening techniques become inadequate in defining the worst cases of test patterns and test sequences out of an enormous number of sequential-combinational candidates and in tracking reliability data following the various stages of product life to provide corrective action. A computerized automatic-optimization stragety is conceived using a systematic approach based on statistical, cumulative and time dependent processes. It integrates device characterization, on-line screening, product and subsequent reliability monitoring via distributed data base management in a closed-loop self-corrective manner. Preliminary evaluation of the intelligent test pattern/sequence generation has been conducted for on-line device screening; the conceived algorithm detects 99 percent of the total defects and consumes only 10 percent test-time of the conventional approach, a significant savings in cost, labor, and equipment expenditure requirement. This test strategy shows the approach to combat ever increasing device complexity while still providing a substantially improved performance-to-cost ratio.

7. Industry/Joint Services Automatic Test Project - Charter and Organization

Aerospace Industries Association

Electronics Industries Association
National Security Industrial Association
Shipbuilders Council of America
American Electronics Association

March 1978

Abstract

Describes the original charter and organization and changes thereto that resulted in the Industry/Joint Services Automatic Test Project and the follow-on Industry/Joint Services Automatic Test Conference and Workshop

8. ATE Newsletter Vol. 2, No. 1, June 1979; Vol. 2, No. 2, October 1979

Naval Material Command

9. Operator, Organizational Direct Support and General Support Maintenance Manual for AN/TSM-93 (Land Combat Support System)

TM 9-4935-552-14/1, 2, 3

10. U.S. Roland Support System

Boeing Aerospace Company

February 1979

Abstract

This document provides a description of the Guided Missile System, Intercept-Aerial: AN/GSG-11 (XO-1) (V) 1, (U.S. Roland Weapon System). The U.S. Roland Weapon System is composed of the Guided Missile System, Intercept-Aerial: AN/GSG-11(O-1) (V) 2, (Fire Unit), the Guided Missile, Intercept-

Aerial: XMIM-115 (Missile) and Carrier, Air Defense Missile System: XM975 vehicle. The principal emphasisis of this brochure is familiarization with the Support System of U.S. Roland.

11. Weapon System Roland - Firing Unit Support

Euro Missile

Abstract

Discusses the four levels of maintenance for the Roland System.

12. Land Combat Support System (LCSS)

RCA - Government and Commercial Systems - Aerospace Systems Division

Abstract

Brochure describing the LCSS

13. Industry/Joint Services Automatic Test Conference and Workshop

Aerospace Industries Association
Electronics Industries Association
National Security Industrial Association
Shipbuilcers Council of America
American Electronics Association

April 3-7, 1978

Abstract

These proceedings contain approximately 215 papers presented during the conference.

14. Industry/Joint Services Automatic Test Project - Final Report - Executive Summary

Aerospace Industries Association
Electronics Industries Association
National Security Industrial Association
Shipbuilders Council of America
American Electronics Association

December 1979

Abstract

This report presents a summary of the eleven key recommendations of the Industry/Joint Services Automatic Test Project.

15. ATE Software Needs in the Army

Helmuth M. Kaunzinger
U.S. Army, CORADCOM

April 1978

Abstract

For minimal life-cycle cost of ATE, we need standardization of high order programming languages and on high order languages (HOL), used to translate unit under test programs into executable code or direct execution (in compiler/run time systems or interpreters). Also needed are probe listings and high quality documentation of operating systems and support software including compilers and necessary library routines for HOL translating languages. Use of proprietary software is no longer desirable.

16. Automatic Test Equipment - A Navy Approach

Angelo R. Papa
Naval Air Engineering Center
Lakehurst, New Jersey

April 1978

Abstract

The main theme of this paper is a Navy approach to the continually expanding field of ATE and specifically the effect it has on the software associated with it. The paper briefly describes, from a management standpoint, the problems associated with the existing proliferation, and highlights the proposed solutions specified in the NAVAIR ATE Program Plan, soon to be released. It is intended to urge both the military and industry to follow a common path to ensure the attainment of the long-term goals of that plan.

17. ATE Software Documentation Requirements

P.A. Rhodes
Naval Ocean System Center
San Diego, California

April 1978

Abstract

ATE software should be documented to standards; the services need to review and evaluate each software document during development; the software should be easily testable by an independent third party; and, at turn-over to the service, should pass acceptance testing with no work-arounds.

18. Requirements Communication

Wendall R. Fleming
Technology Development Corporation
Sunnyvale, California

April 1978

Abstract

Accurate requirements communication is critical to effective functioning of the modern design process. However, little has really been done to help ensure the accuracy of such communications. Ambiquity, misunderstanding, and the resulting frustration all create overly complex systems, non-performing devices and mismatched system components. The natural result of such inefficiencies is more cost, program delays and weapon systems which cannot totally perform their prime mission (performance compromise). This paper attempts to characterize some of the causes for such communication breakdowns and postulates some likely approaches to improving the reliability of the requirements communication process. Additionally, the paper examines some past experiences illustrating the problem and its impacts while suggesting some specific solutions that should be considered now.

19. Test Software Cost Estimation, TRW Experience and Approach

Don Broutt
TRW
Redondo Beach, California

April 1978

Abstract

A software cost estimation technique was developed from two existing data bases. Software configuration control required one data base to be generated, and project cost collection and reporting requirements provided the other data base. Analysis of these data provides historical cost per line for each type of software plus the ratio of support to application software. This information can then be used for "bottoms up" cost estimation.

20. ATE - Software Quality Assurance

P.A. Rhodes
Naval Ocean Systems Center
San Diego, California

April 1978

Abstract

The Navy needs to know that ATE software is being developed to Navy documentation standards; that change control is mandated; that the company has a software QA program in effect in accordance with MIL-S-52779; and that the delivered package is what the Navy bought and paid for under contract.

21. ATE Software Cost Drivers in Relation to RCA Price S Parameters

David A Hendrickson
Honeywell Avionics Division
St. Louis Park, Minnesota

April 1978

Abstract

Every year vast sums of money are spent on Automatic or Semi-Automatic Test Equipment and approximately half of the money is spent on ATE software. With such high annual expenditures comes associated risks in accurately estimating the cost to design, develop, test, document, and maintain automatic test and diagnostic computer programs over the life of the host ATE system. A methodology for the collection of segregated and meaningful actual costs from previous or current ATE software development projects is required to permit future "calibration" of a software cost estimating model such as the RCA PRICE S model. Since ATE software projects are typically very large (i.e., test and fault isolate all failures in all modules of an avionic flight control system), greater emphasis is put on the availability of automatic software design, coding, validation, documentation and maintenance tools. A much greater potential for return on investment which improves ATE software development productivity exists if one is delivering 30 million debugged ATE machine instructions for maintaining an avionics system as opposed to delivering the avionics system itself with only 30 thousand operation flight program machine instructions. At least one attempt at "calibrating" the RCA PRICE S model for ATE software has failed and several guidelines have been generated for recording ATE software cost data which would enhance future attempts at "calibrating". There is still no known reason why a PRICE S type model cannot be "calibrated" for ATE software.

22. Current Appoaches to Maintenance of DOD ATE Software; Issues and Challenges

Michael J. Gooding
Honeywell Avionics Division
St. Louis, Minnesota

April 1978

Abstract

This paper addresses some issues and challenges associated with the maintenace of DOD ATE Software. The paper raises several key issues that present challenges to ATE Software Projects. These challenges are expanded upon and solutions are detailed to show current approaches to meet these challenges and to deal with these important issues for the DOD.

23. Test System Readiness Testing

Don Broutt
TRW
Redondo Beach, California

April 1978

Abstract

A systems approach to test system and test software design can maximize system readiness test capability while minimizing the cost of developing software for this purpose. Selected modules from calibration programs and test programs are utilized to form a system readiness test program. This technique is applicable to

projects where the test set is large and complex, and test times are lengthy.

24. Software Approach to ATE Self-Test

John W. Slattery
General Dynamics Electronic Division
San Diego, California

April 1978

Abstract

Increasing ATE complexity made ATE maintainability more difficult. Competent ATE self-test software is now an essential element in providing adequate ATE availability. This paper discusses the requirements of ATE self-test software, possible design approaches and desirable diagnostic software characteristics. It also addresses the impact of ATE self-test on the ATE system software and hardware. Documentation and quality assurance approaches to self-test software are also discussed.

25. Versatile Automatic Test Systems Using the ATLAS and IEEE-488 Standards in a Distributive Processing Network

Larry Sollman
Naval Weapons Support Center
Crane, Indiana

April 1978

Abstract

The ATLAS standard test language, the IEEE-488 standard hardware interface and the distributive processing concept can be combined to form functional building-

block-oriented automatic test systems. These blocks, being test instruments, allow the user to create any system as dictated by his or her requirements, yet the functional nature of the system confines the software effort to the ATLAS test program generation. The small user can especially benefit since the required functional blocks can be precisely matched with his or her limited resources. However, all users can enjoy the low hardware cost of instruments and utilize the versatility of the functional building-block approach.

26. The Benefits and Costs of Standardization

Dr. James R. Reeder
Westinghouse Electric Corporation
Hunt Valley, Maryland

April 1978

Abstract

This presentation is designed to initiate a workshop discussion to develop the pros/cons and meaningful criteria for software standardization. It examines potential benefits such as the reduction of logistics costs associated with Test-Program-Set preparation, training, and technical documentation. Pitfalls to standardization including technical obsolescence, standardization to the wrong level, and the application of inflexible standards are also examined.

27. Software Development Facilities

David B. Loveman
Massachusetts Computer Associates, Inc.
Wakefield, Massachusetts

April 1978

Abstract

Software development for automatic test equipment consists of three distinct phases: first, the system software is constructed; second, the system software is used to build test programs; third, the operational test programs are executed. These three phases are different, and required different sets of human and machine resources.

28. Digital System Modeling for ATG

Dr. Fuh-lin Wang
Grumman Aerospace Corporation
Bethpage, New York

April 1978

Abstract

For an Automatic Test Generation (ATG) system to be considered adequate, it must include sequential primitives as well as combinational gates in the UUT modeling. With the advent of high density chips, an even higher (functional) level of modeling becomes mandatory. For ultra high density chips logic "representatives" and/or "black boxes" may have to be used. The basic ATG goals are to simulate UUTs containing those chips under normal and failed conditions,

and to create test patterns automatically by algorithms. The tests should detect at least the peripheral pin failures for all chips, even when some of the high density chips are embedded in random logic.

29. Initialization of Sequential Systems

Dr. Fuh-lin Wang
Grumman Aerospace Corporation
Bethpage, New York

April 1978

Abstract

A global initialization procedure which can bring the memory elements of a digital system from unknown to known state is described in this paper. Its requirements, limitations, and merits are discussed. Finally, practical strategies on implementation and applications are discussed.

30. CAD Oriented Measures of Testability

R. Saeks
Texas Tech University
Lubbock, Texas

April 1978

Abstract

Measures of testability for both analog and digital systems which can be incorporated into a computer-aided design package are surveyed. The application of these measures for evaluating and improving system diagnosability is discussed.

31. Practical Automatic Test Program Generation Constraints

Q. Ford Wilson
Ogden Air Logistics Center
Hill AFB, Utah

Douglas B. Day
Aeronautical Systems Division
Wright-Patterson AFB, Ohio

April 1978

Abstract

This paper discusses the practical constraints on ATPG as defined by using organizations. Topics such as typical failure modes, test program development, maintenance and desired ATPG design constraints are discussed in detail.

32. An Overview of Analog Fault Isolation Techniques

H. H. Schreiber
Grumman Aerospace Corporation
Bethpage, New York

April 1978

Abstract

The generic classes of Fault Isolation are Fault Analysis and Fault Dictionary. These are similar to the two branches of statistical inference: estimation (of network element values) and hypothesis testing (deciding which networks elements have drifted out of tolerance) respectively. In addition, the generic classes are distinguished by where computer simulation

takes place in the Fault Isolation cycle -- after testing on the ATE for Fault Analysis, and prior to testing on the ATE for Fault Dictionary. Thus, Fault Analysis emphasizes development of computer aided simulation models, whereas Fault Dictionary generally may take advantage of more effective modelling as it is developed. Each of the generic analog Fault Isolation methods known to be under investigation is discussed.

33. Nonlinear Device Modeling

J. D. Bastian
Rockwell International
Anaheim, California

April 1978

Abstract

Models for the basic circuit devices (e.g. transistors, diodes, FETs, etc.) in an analog network are required in the computerized analysis techniques which are employed in the development of Test Program Sets. This paper examines the degree of device modeling required, method of fault insertion, power dissipation and temperature effects, and the automatic faulting of overstressed device models (secondary failure).

34. Digital Filters as Analog Circuit Models

Dr. W. A. Plice
Honeywell, Inc.

April 1978

Abstract

This paper discusses the use of digital filters as models of nonlinear analog circuits for use in an automatic analog test program generator. The filters are digital equivalents of state variable models of the unit under test.

35. Modeling Techniques for Analog Circuit Fault Analysis

Timothy N. Trick
University of Illinois
Urbana, Illinois

April 1978

Abstract

This paper summaries some of the common techniques used in the design of ATE for the fault analysis of analog circuits and the role that modeling plays in the effectiveness of these techniques.

36. Fault Diagnosis of Large-Scale Analog Systems - A Tearing Method Approach

Ruey-wen Liu
University of California
Berkeley, California

April 1978

Abstract

The problem of fault diagnosis of large-scale analog systems is both large-scale and nonlinear. The large-scale aspect of the problem can be dealt with by a decomposition. It is implemented by a tearing process which decomposes a large circuit into diagnosable circuit modules. The nonlinear aspect

of the problem can be dealt with by further requiring the circuit modules to be linearly diagnosable. The order of the reduction of the cost of diagnosis can be exponential.

37. Pre-ATE Program Generation

J. D. Bastian
Rockwell International
Anaheim, California

April 1978

Abstract

Program generation generally involves the use of a computer simulator program to either aid in, or actually generate Test Program Sets. This is usually performed prior to the actual test on the ATE - Pre-ATE Program Generation. For analog circuits, the difficulty of defining precise device failures and the availability of a mini-computer as a part of the ATE configuration has resulted in emphasis on a reverse simulation approach. This latter approach would require input data from the item under test prior to the computer program being run - Post-ATE Program Generation. This paper will examine some of the limitations of a Post-ATE Program Generation and discuss implementation of a Pre-ATE Program Generation.

38. A Program For Fault Analysis of Analog Networks

Dr. Michael M. Vartanian
Widener College
Chester, Pennsylvania

April 1978

Abstract

This paper describes a parametric fault identification program for linear, analog UUTs. The program's basic concepts, its algorithm as well as its results are presented. Two related programs are also presented and compared. The program is simple to use, easy to implement and runs on a mini-computer. It is designed to analyze any analog, linear UUT and it makes no prerequisites as to test points nor does it require specialized testing but works with normal dc and ac voltage and/or current measurements.

39. On the Use of Deductive Models for Automatic Generation of Test Program for Analog Circuits

R. T. Chien
University of Illinois
Urbana, Illinois

April 1978

Abstract

An artificial intelligence approach is described for the automatic generation of test programs of analog circuits. The test programs are used in conjunction with ATE for isolation of faults in circuit boards. This approach is basically a computerization of the troubleshooting process adopted by a skilled technician. The first step is partitioning of the circuit in question into several or a dozen subcircuits each of which are functionally meaningful from the point of view of signal-processing. Signal tracing methods

are then used to isolate the fault to a single subcircuit. Fault isolation within a single subcircuit to the replaceable unit is accomplished through circuit-specific deductive models. The central feature of a deductive model is a set of rules for fault isolation. These rules are active procedures for automatic test generation. When a subcircuit is fed to a deductive model the output is a test program automatically generated by the model.

40. Fault Detection Isolation Operational Test Experience

Captain David C. Peterschmidt, USAF
Air Force Test & Evaluation Center
Kirtland AFB, New Mexico

April 1978

Abstract

The United States Air Force has seen a phenomenal growth in the complexity and sophistication of its weapon systems in the last ten years. This growth has been centered primarily around avionics components. In an effort to keep support of these complex systems costs effective, automated Fault Detection and Isolation (FDI) systems have been introduced. This has been accomplished primarily through the use of Built-In Test (BIT) and Fault Isolation Test (FIT) equipment. Unfortunately, the Air Force Test and Evaluation Center's experience in the Operational Testing of BIT/FIT has shown these systems fall far short of their mark. Instead of being an aid in supporting a complex system, BIT/FIT has proven to be more troublesome and less reliable than some of the

systems they were to enhance. Given our Armed Forces manpower is not projected to increase in the near term years, BIT/FIT's inability to significantly aid in the support of complex avionics system could have a major impact on the Air Force and other services' decisions to accept or reject further growth in weapon system sophistication and complexity.

41. CITS - Tommorrows Test System Today

Kenneth Derbyshire
Rockwell International
Los Angeles, California

April 1978

Abstract

The Central Integrated Test System (CITS), developed for the B-1 aircraft allows the B-1 to meet self-sufficiency and flight hours to maintenance hours requirements of an advanced aircraft. CITS continuously monitors all aircraft subsystems in flight and on the ground, displays/records failed modes of operation, and fault isolates to the LRU level. Maintenance actions are accomplished using the CITS supplied failure data, and system operation reverified utilizing the CITS active ground tests. The need for ground support equipment has been greatly reduced through the use of CITS. This paper presents results of the development of the B-1 CITS, the design approach, the implementation of the hardware and software, and the planned use of CITS in an operational environment.

42. Shop Test Success is a Function of the Airborne System Design

Gordon R. England
General Dynamics Corporation
Fort Worth, Texas

April 1978

Abstract

The F-16 avionic system is designed with emphasis on comprehensive built-in-test and fault isolation. Mature subsystems were selected so that design talent could concentrate on supportability. The pilot has an indication of the severity of avionic failures to assess operational impacts while the maintenance personnel have functional fault data to assist in shop replaceable unit fault isolation. The avionic fault detection and isolation design is tested early. Shop Test Equipment is tested early and in an operational configuration. Technical Orders are verified long before deployment. Source data for test equipment design is verified by analysis and by test. The result is a highly effective organizational level test capability.

43. BIT as an Integral Part of the System Design

Raif Yanney
Hughes Aircraft Company
Culver City, California

April 1978

Abstract

The feasibility of including BIT as an integral part of the system, in this case microprogrammed

data processors, instead of being added to the system is discussed. Also techniques like the use of hardware, software and/or firmware to implement BIT, the use of special test instructions, the use of residual microprogram control and using a building block approach to aid in the design and evaluation of BIT are presented.

44. Testability Design Process

William L. Keiner
Naval Surface Weapons Center
Dahlgren, Virginia

April 1978

Abstract

Design for Testability is a systematic process for incorporating testability into a design and must include a means by which the testability effectiveness may be quantified and evaluated. Various measures of testability may be defined which address a design's inherent potential to be tested. Other measures address a combination of the design, including its failure modes, and the test process itself, including BIT, ATE, and manual test. It is the latter, more comprehensive measures that are most meaningful in establishing a framework for specifying and evaluating testability in designs. The use of such measures requires the consideration of test stimulus/response for hardware much earlier in the design cycle than is presently done.

45. A Study of a Standard Built-In-Test Circuit

James B. Clary
Research Triangle Institute
Research Triangle Park, North Carolina

April 1978

Abstract

The advent of low-cost digital circuitry coupled with the widespread use of modular hardware by the military has brought about the need for integral fault detection techniques. The study reported here emphasized the use of BIT for fault detection at the module level. This study considered both hardware and information redundant approaches to BIT. The present paper focuses on information redundant approaches which were exploited to derive a standard BIT approach to on-line continuous fault monitoring in modular digital systems.

46. Digital Integrated Test System Improves Testability

Craig D. Brown
Lear Siegler, Inc.
Grand Rapids, Michigan

April 1978

Abstract

Advancements in the sophistication of aircraft avionics require similar advancements in test capability to eliminate the need for very highly skilled maintenance personnel, to increase confidence in mission success, and to reduce test

hardware requirements. When avionics subsystems and processors communicate on a multiplex data bus the integrated test system software performs preflight, inflight, and postflight tests to detect and diagnose system faults with high confidence at low cost.

47. Fault Tolerance Using Self Checking Building-Block Computers

David A. Rennels
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

April 1978

Abstract

It is becoming clear that the use of VLSI technology will allow construction of self-checking computers at very low cost. This paper describes a small set of VLSI building-block circuits which can be used with off-the-shelf microprocessors and memories to build computers which check themselves during normal operation. These computers are designed so that they can be connected into a network with backup spares to provide fault-tolerant operation, i.e., automated recovery from faults.

48. Specifying Built-In-Test

R. Meyer
Hughes Aircraft Company
Culver City, California

April 1978

Abstract

The BIT requirements in a typical radar procurement specification are reviewed. Ambiguities are found which should be corrected. Suggestions are made to improve the specification of BIT and to correlate the BIT requirements with the performance requirements. An alternate BIT thoroughness calculation which directs attention to the untested functions is suggested.

49. Considerations for Sensors in Nonelectronic Systems Testing

William R. McWhirter, Jr.
Naval Ship Research and Development Center
Annapolis, Maryland

April 1978

Abstract

This paper discusses the broad issue of applying electronic instrumentation technology to test and to monitor the condition of machinery systems. The importance of sensors and transducers is investigated in relation to machine "testability" and the employment of various diagnostic techniques. The success of machinery testing is dependent on a detailed knowledge of the failure modes and effects of the unit under test. A discussion of some state-of-the-art sensors for nonelectronic systems testing is included.

50. Considerations for Establishing Cost Effectiveness for ATE Machinery Testing

Sheldon Dockswell
Hughes Aircraft Company
Los Angeles, California

April 1978

Abstract

This paper addresses extending the justification of expenditures for developing and applying new techniques based on savings in maintenance resources. It includes the potential for increasing the capability for mission accomplishment. The discussion includes methods for establishing the appropriate trade-offs by using system availabilities as a basis.

51. The Evaluation of Automated Systems With Emphasis of Meeting Basic Requirements

Henry H. Johnston
Sperry Marine Systems
Great Neck, New York

April 1978

Abstract

Automation systems designers often indulge in over automation. A cost-effective system analysis is discussed which leads to determining optimum automation parameters.

52. The Challenge of New Technology for Avionics Testing

Paul R. Owens, Major, USAF
HQ Air Force Systems Command
Andrews AFB, Maryland

April 1978

Abstract

A brief assessment is given of where Air Force avionics testing is today in terms of technology and testing methods. From a review of technology developments changes in avionics testing methodologies, equipment, and requirements are forecast.

53. Microwave Instrumentation - Current and Future Technology

Earl T. Kittinger
Rockwell International Corporation
Los Angeles, California

April 1978

Abstract

New technology in the microwave area is driving requirements for testing and test equipment to higher frequency ranges and to greater accuracies. The new technology for microwaves is in the millimeter range. Equipment currently in use in the 1 to 18 GHz range cannot be easily adapted to millimeter microwave application. One approach to this type of measurement is the application of newly developed electro-optical techniques to instrumentation and signal generation. Other elements requiring parallel development are: Standards for millimeter microwave and optical

measurements; procedures for making standard measurements; and investigation of material behavior at high frequencies.

54. Trends and Needs in Test Methods and Equipment

Frank P. Cavanaugh
Rockwell International
Los Angeles, California

April 1978

Abstract

Various new technologies were examined in the light of impact on test equipment or methods, the rapidity of growth of the technology, and/or whether or not it could be expected to be put into use by any of the Military Services. Three major technological areas emerged not as the only possible choices but as those which more closely fit the criteria. These areas are microprocessors/microcomputers, lasers, and fiber optics. The intent of this paper is not to answer questions about these areas, or the test methods involved with them, but rather to raise questions which will broaden the base of this committee inquiries and, consequently, maximize its output.

55. Recommended Methods for Technology Forecasting and Assessment

Max Frank
Bendix Research Laboratories
Southfield, Michigan

April 1978

Abstract

A number of technology forecasting methods are considered along with their capabilities and limitations. Methods suitable for forecasting manufacturing and testing technologies are recommended.

56. Semiconductor Memory Horizons

Paul D. Wohlfarth
Tektronix, Inc.
Beaverton, Oregon

April 1978

Abstract

This paper gives an overview of the many types of solid state memories that exist. Some trends in development are pointed out. Testing problems are discussed along with a few suggested solutions.

57. Custom High Speed Digital Technologies

D. M. Giles
TRW, Inc.
Los Angeles, California

April 1978

Abstract

Custom high speed (400 to 5,000 MHz) digital circuits have been developed in both Silicon (Si) and Gallium Arsenide (GaAs) technologies. Examples of monlithic circuits designed using Si and GaAs technologies are presented and the

probable impact of automated testing of these complex digital circuits at high frequencies is discussed.

58. Conceptual Applications of Fiber Optics to Built-In-Test

Hubert B. Muench
Magnavox
Fort Wayne, Indiana

April 1978

Abstract

Fiber optics has become a fast moving, expanding technology which is full of solutions looking for problems. This paper describes some applications of fiber optics technology to BIT which utilize some of the unique characteristics of fiber optics. The three basic operational modes for fiber optics (illumination, communication, and imaging) are presented individually and in combination to illustrate a few of many ways in which fiber optics can be implemented.

59. Current Methods of Optical Radiation Measurement

W. M. Doyle
Laser Precision Corporation
Arvine, California

April 1978

Abstract

This paper reviews the various types of commercial instrumentation presently available for the measurement of optical radiation. It covers the

measurement of total power, pulsed energy, spatial distribution, and spectral distribution. In addition, it outlines the methods available for instrument calibration and discusses various new developments which could be brought to bear in solving existing measurement problems.

60. Laser Rangefinder Built-In-Test Equipment

D. B. Keever
Hughes Aircraft Company
Los Angeles, California

April 1978

Abstract

It is difficult to measure laser receiver sensitivity, even in the laboratory, and laser safety requirements preclude realistic operational testing in many field environments. Consequently, it is difficult to determine whether a laser rangefinder system is serviceable or needs repair. Hughes has developed a minaturized collimator optical delay line ("SORT") as BITE for laser systems which solves this problem.

61. Microcomputer-Based Built-In-Test Techniques

J. W. Gault
North Carolina State University
Raleigh, North Carolina

April 1978

Abstract

The microcomputer has been billed as a panacea for a number of applications. The question of interest here is, "can a microcomputer be applied as an effective BIT element in complex, modular digital electronic systems?". This discussion will begin with a general overview of the area and end with a discussion of the cost/effectiveness criteria which may be applicable in answering this question.

62. Microprocessor Optimized Testing

Ronald L. Earp
Research Triangle Institute
Research Triangle Park, North Carolina

Norman R. Bell
North Carolina State University
Raleigh, North Carolina

April 1978

Abstract

The test engineer involved in testing LSI microprocessors is faced with a significant problem. A powerful instruction set is one criterion for gaining market acceptance for a particular microprocessor, which generally dictates that testing is neither straight-forward nor simple, due to the complexity of the microprocessor. The microprocessor is not an interconnection of logic elements, in either a completely random or completely well-ordered structure (such as in a RAM or ROM), therefore it does not lend itself to conventional test methods.

This work presents an up-to-date survey of a number of the methods in current use for microprocessor testing. Advantages and disadvantages of the methods are discussed, with particular attention being focused on efficient and optimized techniques. The work concludes by recommending further research study in this area in order to define applicable figures of merit for microprocessor testing techniques, to allow test comparisons.

63. Microelectronic Test Patterns for Use in Procuring LSICs

Martin G. Buehler
Naval Bureau of Standards
Washington, D.C.

April 1978

Abstract

The complexity of today's integrated circuits requires new procedures for evaluating the performance of emerging fabrication processes and for insuring that reliability is built into mature components. One approach, currently being developed at NBS, involves the Process Validation Wafer concept which is useful in assessing the merits of a new technology and in establishing the base-line performance of an existing process. One key to built-in reliability is parameter uniformity. This is illustrated by a wafer map showing the variability in bipolar transistor gain across a silicon wafer.

64. Analyzing Available Microprocessor Capacity for On-Line BIT

Charles W. Einolf, Jr.
Westinghouse Electric Corporation
Pittsburgh, Pennsylvania

April 1978

Abstract

The advance of technology in electronics has had a tremendous impact upon the design of sophisticated systems. The introduction of microprocessors has led to a rapid reduction in physical size while improving the overall system design. The microprocessor has permitted the distribution of processing throughout the system thereby reducing system complexity. Although the microprocessor in itself is complex, it can be given the intelligence to do more than its immediate application. The processor is capable of incorporating On-Line BIT into system functions. On-Line BIT includes any test function within the system which is repeatedly performed during system operation, but does not interfere with the system performance.

This presentation discusses the various categories of On-Line BIT, system processes which can utilize On-Line BIT and the types of On-Line BIT which can be achieved within microprocessor systems. The impact of On-Line BIT upon system reliability and availability is also discussed.

65. In-Service Testability of Mass Memory Systems

Jerome J. Gross
Electronic Memories and Magnetics Corporation
Chatsworth, California

April 1978

Abstract

This paper explores the problems associated with system readiness and performance monitoring of mass memory systems. Large "smart" mass memory systems are required to support the large data processing requirements. The problem with these mass memory systems is the achievement of high availability. This must be achieved and techniques of built-in test must be considered in the design of mass memory systems. Various methods such as performance monitoring using built-in microprocessors and error detect and correct should be considered to ensure maximum availability of mass memory systems.

66. Design for Testability of PC Boards Containing Microprocessors

Daniel F. Crowley
GenRad, Inc.

April 1978

Abstract

This paper demonstrates that, with a little extra care in the design stage, testing a PC board containing a microprocessor can be a straight-forward process. This "designed-in" testability involves partitioning of board functions and providing for visibility and special control

capability for the tester. This may include providing the ability for the tester to disable internal board processes and to control speed or timing. It also implies providing tester visibility to control signals and buses and can even involve selection of devices used in the design. These ideas, developed for general-purpose microprocessors such as the 8080, Z80, or 6800, can also be applied to boards incorporating special-purpose microprocessors such as single-chip microcomputers and bit-slice component designs.

67. ATE Hardware Standardization

Arnold M. Greenspan
AMG Associates, Inc.
Arlington, Virginia

April 1978

Abstract

The issue of standardization of ATE has been discussed within the Department of Defense and some effort to implement this philosophy has been attempted. These attempts have not had any major impact on the overall inventory of ATE for numerous reasons. Among these have been lack of definitive standardization policy for ATE, variations in ATE procurements across programs and rapid evolution of ATE technology. However, today the general acceptance within the tri-services of the "Family of Testers" concept has made this issue a more pressing concern. In addition, the Family of Testers approach serves to provide a basis by which standardization can be viably implemented. This overview will present some

of the factors which must be considered in pursuit of hardware standardization for ATE.

68. Automatic Testing Technology Centers

George W. Neumann
Naval Material Command
Washington, D.C.

April 1978

Abstract

The need for all type of information relative to automatic testing is essential if the Services are going to take advantage of "lessons learned". This paper discusses the requirements for Joint Services/Industry Automatic Testing Technology Centers, some of the problems inherent in establishing and operating these Centers and a cursory look at some existing Centers. In conclusion, a recommendation is made to the Industry/Joint Services Project for considerations of the most cost effective mix of Technology Centers.

69. Universal Pin Concept

Frank Moebus
General Dynamics
San Diego, California

April 1978

Abstract

This report will discuss a number of misconceptions about the universal pin revealed by the Task Group

1(H) Survey. It will also include a brief discussion of the key characteristics of a modern universal pin, along with its probable architecture. The report concludes with a projection of the future ahead for the Universal Pin Concept.

70. Human Aspects of ATE

Dr. Lewis F. Hanes and Mr. William W. Ramage
Westinghouse Electric Corporation
Pittsburgh, Pennsylvania

Mr. Gerald E. Proctor
Westinghouse Electric Corporation
Hunt Valley, Maryland

April 1978

Abstract

The purpose of this paper is to initiate and stimulate a workshop discussion regarding the human operator/maintainer-ATE interface. Workshop objectives are to identify and discuss important issues related to the interface, and to consider the scope of interface guidelines and standards. Possible important interface issues identified in this paper include workplace arrangement, information availability, equipment design, and environment and motivation. In addition, personnel skills and training are mentioned. The applicability of existing standards and knowledge to the interface is considered.

71. A Non-IEEE Bus View of the Computer Interface

Frank Moebus
General Dynamics
San Diego, California

April 1978

Abstract

This report discusses important computer interface characteristics which should be considered in specifying new test systems. A discussion is included of the characteristics of the IEEE 488 Bus which tends to inhibit implementing the desired computer interface characteristics, consequently driving up costs and reducing software efficiency.

72. Interface Effects on Test Program Sets

George R. Byrd
Harris Corporation
Syosset, New York

April 1978

Abstract

The interface is not defined in most ATE systems in a standardized way or with a standardized Test Program Set (TPS) development procses in mind. These factors have contributed to high TPS development costs, complication and proliferation of interface devices, and potentially ineffective TPS's. This paper explores the effects of interface design on test program sets. Past experiences are assessed in terms of establishing the design criteria for an idealized interface geared to reduce TPS costs and improve

TPS quality. Such an interface is found to be one which can be defined and standardized from existing data, possesses reasonable flexibility, can be incrementally sized and organized, and is consistent with usage standardization controls achievable by software. A proposed interface design concept best fitting these criteria is presented and appropriate recommendations are made for its further development.

73. Navy Metrology and Calibration Program and Automatic Test Equipment Calibration

Delbert H. Caldwell
Navy Metrology Engineering Center
Pomono, California

April 1968

Abstract

The requirements for assuring the quality of ATE test and measurement capabilities are discussed. The Navy Metrology and Calibration Program objectives and methods for supporting Test, Measurement, and Diagnostic Equipment as well as ATE are given. Key improvement areas for ATE calibration are identified along with the status of current improvement actions.

74. State of Industry ATE Calibration

Dale E. Myers
American Airlines, Inc.

April 1978

Abstract

Sophisticated ATE has been in use in the industry for over 10 years and most companies have learned to operate it economically in a production or maintenance environment. However, advances in the state-of-the-art are continuously pushing the accuracy specifications for measurement equipment closer to the certified accuracy of primary standards. This has created the need for more accurate calibration standards, particularly transfer standards, and reduced certification periods. Documentation records must provide an accurate history of the equipment under certification that starts from the beginning, with initial delivery and acceptance of ATE and leaves a clear history of events that have occurred throughout the useful life of the equipment.

75. ATE System Capability Improvements Via Software

David H. Russell
National Bureau of Standards
Boulder, Colorado

April 1978

Abstract

The accuracy and efficiency of any ATE system can usually be improved by application of software corrections derived through calibration measurements accounting for system losses or variations. Software enhancement of parameters that can and do change creates special problems for the calibration and user community regarding validity, proper application, and verification. As an alternative to using "gold-

plated" measurement standards for overall systems calibration, methods of internal system intercomparisons (self-calibration), partial calibration, UUT fail/pass data, etc., will be discussed.

76. Did You Get What You Paid For?

Marlyn L. Hed
TRW Space Systems
Redondo Beach, California

April 1978

Abstract

The acceptance test planning and evaluation of ATE must start before purchase and not after it is paid for. Metrology and calibration criteria must be considered before design and monitored through acquisition, implementation, operation, and support phases of the ATE. Detailed metrology criteria of evaluation, documentation, timing, technical capability, specification interpretation, calibration interval establishment, etc., is discussed. Calibration reaction mode versus early investment and action opportunities is presented.

77. Assuring Continued Measurement Integrity

Robert J. Ott
Lockheed Missile & Space Company
Silverdale, Washington

April 1978

Abstract

After the ATE has been proven and documented by the customer to meet all applicable performance specifications, safeguards must be implemented to maintain control of the integrity of both hardware and software. ATE presents new unconventional control problems to the calibration quality organization because of the new measurement contribution of software. Considerations are discussed resulting from addition of new or modified UUT requirements, system reconfiguration, new measurement techniques, repair/replacement of system components, as well as calibration interval adjustment and data retention. Organizational capabilities and responsibilities required to achieve measurement integrity are presented.

78. Calibration, Repair, Software Support; Responsibilities

R. B. England
General Dynamics
Pomona, California

April 1978

Abstract

The DOD community is concerned with logistic cost and operational readiness of its weapon system. Today, many of these systems are tested on ATE at various depots and field installations. Periodic calibration, repair and support methods and procedures are established and performed on these ATE's in order to ensure that their operating functions are within acceptable limits and that the basic system integrity is maintainable over pre-

set intervals. This paper discusses some basic problems and questions concerning these methods, procedures and responsibilities. It will be the function of the workshop to further identify and examine these methods and responsibilities in order to arrive at some recommendations or common solutions. The remainder of the paper discusses what the author believes is the primary problem concerning the support of military ATE, namely: "The increasingly difficult task DOD personnel have in repairing complex field ATE."

79. System Approach to Calibration of ATE

Ravi Shah
Martin Marietta Aerospace
Orlando, Florida

Eugene Land
DRSMI-NLTL
Director for Maintenance & Engineering
U.S. Army Missile Materiel Readiness Command
Redstone Arsenal, Alabama

April 1978

Abstract

DOD uses more than one method of calibrating ATE. The classical approaches prevalent are compared to the opportunities, requirements, and effectiveness of a "systems" or composite process of calibration. Industry trends, productivity improvement potential, calibration interval adjustment schemes, possible versus traditional, UUT interface versus external calibration of individual

instruments, etc., is presented, as well as the prerequisite for "systems" calibration.

80. The Future Role of Systems Engineering

William R. Wakefield and
Howard S. Kuehn
Westinghouse Electric Corporation
Hunt Valley, Maryland

April 1978

Abstract

The Military, Industry and Academic communities have all identified Systems Engineering differently. During yesteryear, the "General Engineer" had knowledge and cognizance over a number of Specialists and performed as the integrator for relative simple systems. During the era of engineering specialists, engineers perfomed their tasks rather independently; control, at the system level, resulted from the integrity of each discipline. Documentation proliferated. Inevitably, sophisticated systems began accruing high costs of acquisition plus very high costs of ownership. The Military began searching for a more cost-effective approach to a system's acquisition. More documentation developed to provide acquisition guidance, such as MIL-STD-1388. In spite of savings, areas of a system and its support suffered cost escalation. The big problem lies at the system level because the system design dictates the degree of support costs; the solution is for rigidly controlled system design and equally controlled ILS resources design. The equivalent to the prior "General Engineer" is

sorely needed and Systems Engineering must perform that role, must dictate the design of the system, its elements of support and must be a composite of all of the analytical engineering disciplines. Systems Engineering must critically view the whole system design from a broad-based vantage point of total operational, support, producibility and utility requirements, to assure that a system is "designed to" all requirements and to stop resources proliferation and high life cycle costs.

81. Integrated Logistics Systems Analysis for Automatic Test Equipment

J. E. Barker
ATE Associates, Inc.
Northridge, California

William C. Johnson
Economics Technology Associates, Inc.
Marina Del Rey, California

April 1978

Abstract

This paper describes an integrated logistics systems analysis process for acquisition of automatic test equipment and optimum support of weapon system electronics/avionics. The paper first deals with the organization and identification of critical program/discipline data items. These data items provide information relative to the weapon system program requirements, the engineering logistics operations, disciplines peculiar to the weapon system program, and the data for each discipline. The paper secondly considers the definition of the

data processing requirements necessary to provide analysis, access and retrieval of the information contained in the data items. The paper thirdly defines the analysis procedure and evaluation approach using scientific models peculiarized for the weapon system and constructed for adaptability. The paper last describes various reporting requirements.

82. Risk Analysis In The System Engineering Process

Erasmus E. Feltus
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Hunt Valley, Maryland

April 1978

Abstract

The System Engineer is required to make and to evaluate many decisions during the acquisition process. In many areas these decisions will be based on "expert judgement", due to a lack of concrete design parameters. But it is during these early phases that a majority of the downstream Life Cycle Cost (LCC) (over 80%) is fixed. Risk analysis techniques can be employed to evaluate these judgements and to choose the decisions which have the least risk paths. Support Equipment, especially ATE, is one driver of front-end logistics costs. The decisions to design a system item for use with ATE, on the degree of BIT to incorporate, on a maintenance philosophy to be followed, and on the other support elements required must be evaluated in these early phases. All of these decisions

are highly interdependent and require reduction of inherent risks to minimize LCC. It is doubtful that a procedure can be developed to eliminate risks from decision making, such as the use of a crystal ball. Thus, we must settle for the next best course of action, an estimate of the risk involved in the decision. This paper will discuss the subject of risk analysis, defining the terms and the techniques used to evaluate risks. This paper will also present methods for applying risk analysis techniques, with special emphasis on applications related to ATE and to the MIL-STD-1388 Logistics Support Analysis planning decisions. The discussion will present experience gained on risk analysis during work on warranty models and suggestions applying this experience to the Systems Engineering process.

83. MIL-STD-1388 in Automatic Test Equipment Acquisition

Edward Scott
IBM
Manassas, Virginia

April 1978

Abstract

The discipline of MIL-STD-1388 is germane to an effective design and lifetime support of any product. Proper interpretation and application of MIL-STD-1388 will disclose an optimum support set for each end item and its intended environment. As one means of support element implementation, ATE must be traded off against competitive approaches to obtain the best available set.

84. Improvements in MIL-STD-1388 Logistics Support Analysis

Alexander Gossman
Naval Weapons Engineering
Washington, D.C.

April 1978

Abstract

The Navy began the Logistic Support Analysis (LSA) effort to standardize the logistic dialogue between the designer and the logistician. The Navy effort in LSA has lagged behind the Army but now the Navy effort has been revitalized and is taking the helm again to make improvements in the LSA. The use of the LSA should increase due to the recent actions of Naval Material Command. The first change to the MIL-STD will be the ATE requirements. The LSA is the integrator in the Integrated Logistic Support process and the communication link between the Logistic Elements. LSA is here to stay and should be made to serve the needs of the contractor and the government.

85. The Test Requirements Document - A Key to Improved Electronic Equipment Support

E. E. Johnson, Jr.
Naval Sea Systems Command

April 1978

Abstract

The Test Requirements Document (TRD) is a foundation for the identification of support test equipment, and for the test program/procedures to be supplied

for Fleet electronic equipment support. Acquisition of equipment source data and test requirements as part of the Logistics Support Analysis process will avoid the time and cost penalties incurred by delaying Test Requirements Analyses until the equipment is deployed. Equipment Source Data and Test Requirements standardization required by a TRD will reduce costs further by avoiding acquisition of unnecessary documentation, by improving configuration control and by facilitating validation of the test requirements analysis.

86. Data Base Management - A Tool for Resolving the Data Dilemma

E. Louis Wienecke, III
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April 1978

Abstract

Data base processing is a topic receiving more and more attention for improving data management. This improvement translates into data being managed as a resource so that it is possible to convey information for future use. By marrying current computer software technology in the form of Data Base Management Systems (DBMS) with the information needs which arise during the acquisition process, the data dilemma which currently exists can be resolved. This dilemma comes about because of the inadequacies of handling data using manual systems or conventional electronic data processing. These inadequacies are primarily concerned with data storage and retrieval. That is, accessing only the data elements that are needed,

when they are needed. It is this type of access which is required if a data base is to serve as a true data bank; a repository of historical data to provide future information. The processing of data within a DBMS environment appears to be a feasible approach to establishing data banks containing ATE and Logistics Support Analysis information.

87. Education and Training - Its Importance in the ATE Arena

Dr. Janathin A. Miller
ManTech of New Jersey Corporation
San Diego, California

April 1978

Abstract

This presentation will serve as an introduction and overview of Education and Training Task Group efforts over the past six months. The critical importance of training in both the managment and operator/technician fields will be addressed. The necessity of selecting and employing state-of-the-art instructional technologies to bridge the training gap will be discussed in conjunction with an outline of the objectives, technical approach, evaluative measures and survey techniques utilized by the Task Group to substantiate research findings and results to date.

88. Acquisition Management and the Impact of Future Demands on Project Managers

Harry E. Foster
Naval Weapons Engineering
Washington, D.C.

April 1978

Abstract

Providing the support for Navy aircraft of the future promises to grow more difficult and demanding with time; a task made even more unmanageable by severe budget constraints. By forecasting future logistics requirements, planners will have the lead time needed to meet this challenge. NAVWESA has undertaken the development of such a forecast for NAVAIR's Research and Technology Department. This forecast shows that naval aviation acquisition managers of the 1985-95 decade will be faced with higher quantity procurements, an increased emphasis on cost, and more concern being given to mission requirements.

89. Operation and Maintenance of the Army's AN/USM-410 Test Set, Electronic Equipment

Warren Eatinger
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Materiel Readiness Command
Fort Monmouth, New Jersey

April 1978

Abstract

The Army's AN/USM-410 was formerly called Electronic Quality Assurance Test Equipment (EQUATE) and is a

computer controlled ATE comprised of several subsystems which are installed in a van. These subsystems are: the control, the low frequency measure/stimulus, the radio frequency measurement/stimulus, the microwave (18 GHz) measurement/stimulus, the switching and interface, the power supply, the software, and the van/environmental.

This paper describes the interaction between the ATE and the operator/maintenance personnel. The AN/USM-410 will be described to illustrate its unique capability for operator/equipment interaction which should reduce the skill/knowledge level required of the operator. The AN/USM-410 will also be described to illustrate its modularity and commonality which should reduce the skill/knowledge level required of the maintenance technician.

90. Operator and Technician Tasks for the Heads-Up Display Test Set and Versatile Avionics Shop Test (VAST)

Dr. Paul E. Van Hemel
Naval Training Equipment Center
Orlando, Florida

April 1978

Abstract

The tasks of operators and technicians for the AN/AVM-11 (V), A7-E Heads-Up Display Test Set, and for the AN/USM-247 (V), Versatile Avionics Shop Test (VAST) are described and compared. The tasks fall into overlapping categories that are common to operators and technicians and across types of ATE, with a relatively small proportion identified as tasks specific to operators or

technicians for particular equipment. There may be some tasks, involving analysis of test program sets, that do not fall into the category of tasks traditionally required of operators or technicians. Such tasks may become more important in future generations of ATE.

91. Some Issues Related to the Training of EQUATE, HUD, and VAST Operators, Analysts, and Maintainers

Dr. Alan C. Hundt
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Washington, D.C.

April 1978

Abstract

Authors of the previous papers supported several conclusions: (1) There are many tasks which are common to all ATE jobs, (2) only a few ATE tasks are specific to individual equipment, and (3) the skill and knowledge levels of ATE operators and technicians are lower than the levels which are required without the automatic test equipment. The generalization of these statements is examined in the present discussion, and other issues are also reviewed.

92. Overall Recommendations for Improving ATE Operator/Technician Training in the U.S. Department of Defense

Dr. William J. King
Naval Training Equipment Center
Orlando, Florida

April 1978

Abstract

This paper briefly summarizes some of the newer technologies which could help alleviate the poor throughput of qualified Op/Tech Trainees in ATE. A mix of media utilizing both publications and hardware approaches for training and aiding the technician is discussed. Finally, two basic recommendations are presented which call for (a) representation of human factors/training professionals on all ILS teams at the ATE procurement stage and (b) funded research at the 6.3 and 6.4 levels to transfer some of the newer cost-beneficial training technologies into devices which are usable in the various DOD Training Commands.

93. An Approach to Verification and Validation of Test Program Sets

William Chandler
Support Systems Associates, Inc.
Northport, New York

April 1978

Abstract

An approach to validation of test program sets is offered to replace the either incomplete or too burdensome apporaches used. It consists of using a validation fault set size that is manageable and has a reward/penalty relationship that focuses attention on the all important program development phase. This approach is in use on S-3A VAST Test Program Sets currently in development.

94. Automatic Test Equipment (ATE) Acquisition in the U.S. Navy

F. Liguori
Naval Air Engineering Center
Lakehurst, New Jersey

April 1978

Abstract

Based on years of experience using Automatic Test Equipment to support complex weapon systems, the Navy's Systems Commands are appraoching ATE acquisition in a much more sophisticated fashion. This paper highlights lessons learned and the resultant acquisition philosophy that underlies current procurement policy. It reveals a new, more cooperative attitude toward automatic testing among the Systems Commands and industry, stressing R&D, early and comprehensive management planning, and development of organic capabilities to maintain software.

95. Observations and Example of ATE Acquisition

J. A. Murnane
RCA
Burlington, Massachusetts

April 1978

Abstract

In the acquisition of ATE before contract award the supplier has the following concerns: the identification of the requirement, the customer, the funding and the proper timing of the program. These concerns

have always been difficult to resolve and in the present environment they are more complex and confusing. In spite of this the acquisition of the YAH-64 Advanced Attack Helicopter support equipment is a model of how ATE should be acquired. Considering this program as an example leads to some questions that should be addressed in the ATE community.

96. Vertical Commonality, A Support Alternative

David Alper
Hughes Aircraft Company
Canogo Park, California

Larry Cardo
Gould Ocean Systems Division
Cleveland, Ohio

April 1978

Abstract

Vertical Commonality is defined as the maximum usage of the same support equipment software and hardware at all levels of maintenance. This maintenance support concept has already achieved a record of successful accomplishment on programs in all the services. Normally Vertical Commonality applies at all maintenance levels. A common support problem that exists when different support equipment is used at the various maintenance levels is the prevalence of test inconsistencies. This leads to prolonged back and forth movement of prime units through maintenance echelon pipelines, instead of to the ready for issue storeroom. The prime benefit of

Vertical Commonality is to virtually eliminate this costly loss of prime equipment assets and consequent reduced weapon availability. Factory/depot testing, consistent with field testing is the key. There are many other significant benefits that come with the vertical commonality concepts relative to cost savings and improvement in the quality of maintenance. Test equipment implementation is selected from: existing Ground Support Equipment, new design, or combination; however, the importance of its commonality within the system supported is stressed. Vertical Commonality provides the opportunity for a disciplined, systems level approach to optimize support at all echelons of maintenance from a common data base.

97. Major Problems Facing the Military User of ATE

Anton J. Price
Captain, USAF
HQ Tactical Air Command

April 1978

Abstract

Six major areas of logistical concern and their relevance to future ATE systems are discussed. These six areas are reliability, maintainability, supply support, technical data, support equipment, and personnel training. Areas of concern are discussed in broad terms and detailed specifics are not included. Recommendations are made in each area that have application to future systems. Evolution of Automated Test Equipment cannot be dependent on to cure future problems. Problems

of the past must be addressed in the conceptual phase of the life cycle.

98. Economics of Failure Detection in ATE

K. R. Hilberth
GT&T Industries, Inc.
Van Nuys, California

April 1978

Abstract

Detection of failures in the ATE itself plays an important role in ATE effectiveness. Various elements of ATE and Test Program Set effectiveness will be related to ATE failure detection. Recommendations are offered for further research in this area.

99. ATE Benefits Analysis

Jasper M. Colebank
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Burbank, California

April 1978

Abstract

The objectives and goals of the Benefits Analysis Group are threefold; 1) define ATE benefits, 2) provide quantitative benefits data, and 3) provide a strategy for the Joint Services to reap the benefits. This paper defines ATE benefits in terms that are most meaningful to military planners; e.g., in terms of time and money. A fundamental

conclusion of this paper is that there must be a close bond between designers at all levels, ATE application engineers, and logisticians in order to realize the highest operational readiness at the lowest cost.

100. The Application of Benefits Analysis

Capt. James R. Cooper, USAF
Support Equipment System Office
Wright-Patterson AFB, Ohio

April 1978

Abstract

Implementing improved methods for acquisition, application and operation of ATE is proving to be difficult and time consuming. Current activities in this field are pressing for new concepts which will support the next several generations of weapon systems. Yet, without adequate attention to reducing the acceptance and implementation risks associated with these new concepts, it is likely that their full problem-solving potential will not be realized. The heart of such a risk reduction program is the effective development and application of benefits analysis. The products of benefits analysis hold the key to achieving the full potential of new ATE concepts.

APPENDIX A

TASK DESCRIPTIONS AND RECOMMENDATIONS OF THE INDUSTRY AD HOC ATE PROJECT FOR THE NAVY

The following task descriptions are summaries of both the tasks of each Task Group and their recommendations. The full description of each Task Group and its recommendations are contained in the Final Report of the Industry Ad Hoc Automatic Test Equipment Project dated April 1977.

Task A Description - Research, Development, Test, and Evaluation

A research, development, test, and evaluation program in automated testing techniques must be established in order to prepare for the support of future Navy systems. This program would identify new technologies that should be addressed as well as support promising on-going research and development.

The objective of Task A of the Project was to provide the Navy with detailed programs and recommendations for research, development, test, and evaluation in automated testing techniques for the future. Because of the scope of Task A, it was divided into seven subtasks. Over 150 representatives, from both government and industry, participated in this task.

To obtain the maximum exchange of ideas and thoughts, the Project held an industry-and government-wide workshop in San Diego, California, during the week of April 12, 1976. Approximately 400 people attended. The format of the workshop was informal, with presentations in the seven main topical areas by representatives from both industry and the Department of Defense. Panel discussions, open to all workshop attendees, provided the two-way communication and interchange of ideas. The topics and comments presented by the attendees were considered in the preparation and generation of this report. The proceedings of the workshop were also documented in a separate report.

Task A-1 - Software

Automatic-test-equipment software has become a major contributor to the life-cycle cost of Naval weapon systems. A combination of the increased

reliance on automated techniques, the explosive growth in digital and software technology, and the widespread inexperience in the management and control of software design and production has caused these increased costs.

The Navy needs to consolidate presently available tools, policies, and management techniques, as well as to identify and control existing software cost factors, before exploring new software methodologies.

If no action is taken to analyze the cost and management porblem and then assign task forces to reduce the main cost drivers, it is expected that future programs requiring automatic test equipment will entail the same large cost overruns experienced today.

Recommendations

- It is of paramount importance that the Navy take vigorous action to quantitatively identify software cost drivers and to control their effect upon test-program-set development and maintenance. The software Task Group report presents several specific recommended studies addressed to this need.

- A second and related recommendation is to improve present automatic-test-equipment software management and control methods.

- There should be a judicious standardization of automatic-test-equipment software tools, techniques, and interfaces. What is most important is that test-program-set structure at ATLAS-OPAL langauge covergence areas be emphasized.

- Other recommendations of this report are the need to improve the operational aspects of existing automatic-test software systems and to improve maintenance methods.

Task A-2 - Automatic Test Generation

Automatic test generation systems that perform computer analysis of digital electronic equipments to generate quality test programs are now in use.

Unfortunately, the best of these have been outdistanced by new and evermore complex digital integrated circuit technology. The trend towards the use of large-scale integrated circuits in Navy electronic equipment is certain to make this problem worse. Furthermore, development of automatic test generators for analog equipment is an even more complex process than that for digital equipment, mainly because there are many more ways in which analog circuits can fail. This design problem must be solved because of the wide array of analog equipment used by the fleet, much of which will never be replaced by digital electronics.

Another problem is the lack of a precise language for automatic test generation. This field is so fluid that communication among Navy and Industry people is difficult and information is sometimes misinterpreted.

Recommendations

- Initiate a broad-based research and development program to develop a new generation of digital automatic-test-generators with the following characteristics:
  - Provides functional and primitive circuit modeling
  - Provides automatic optimized pattern generation
  - Capable of detecting more types of circuit failures
  - Allows for guided-probe and other testing techniques
  - Designed for user convenience, with features such as interactive editing, restart capability, and on-line status displays.
- Investigate the use of minicomputer-based automatic test generation systems.
- Sponsor a research and development program for an analog automatic test generation system. This program would:
  - Define analog circuit failures modes

- Develop techniques to model complex and nonlinear circuits and components

- Fund several different approaches and allow for a "fly-off" demonstration.

Task A-3 - Design for Testability

Design for testability is probably the single most important requirement for meeting the Navy's long range goal of supportable systems at affordable costs. Traditional design methods and procedures are incompatible with these objectives. The Navy needs a new design methodology that will result in testable systems.

Testability must be designed into weapon systems from the start. To obtain testability, the Navy must provide the policies, guidelines, procurement procedures, education, management controls, and evaluation techniques necessary to achieve it.

Under present practices, inherent problems in maintenance and support are not seen by Navy management until after the equipment is procured and placed in service. This results in "get-well" programs which are orders of magnitude more costly than early prevention. Fleet readiness also suffers unnecessarily, while "fixes" are being incorporated.

Recommendations

o Sponsor a continuous research and development program to develop new built-in-test techniques for the prime equipment and the means for implementing these at a systems level.

o Develop testability specifications, along with the means for quantitatively measuring this parameter.

o Develop a life-cycle-cost model to provide a tool for evaluating the benefits of testability.

- Improve management by implementing more effective procurement policies, enforcing MIL-STD-1388-1, Logistics Support Analysis, on new programs and instituting testability audit and review procedures.

- Develop an integrated testability design guide as a aid to designers to make new systems more testable.

Task A-4 - Propulsion, Electrical, and Auxiliary Systems Monitoring

The potential savings in fuel, time, and maintenance efforts that can be realized by the introduction of automatic monitoring of non-electronic ship systems offers a significant dollar return. In addition to these direct dollar savings, significant improvement in operational readiness can also be achieved.

The non-military application of automated monitoring and diagnostic techniques has been developed and is in use. International conferences and the technical news media report an increasing degree of such applications in the Merchant Marine--the need is no less imperative in the Navy.

Recommendations

- Undertake a program to identify the shipboard machinery that contributes most heavily to maintenance costs. Define their failure modes and determine optimum sensors and data analysis techniques. Subsequently, design and construct prototype hardware for evaluation at sea.

- Initiate a study team to evaluate the adequacy of existing commercial sensors, and then modify current Navy specifications based on its findings. Subsequently, prepare lists of available sensors and then establish research and development programs to fill any identified gaps.

- Develop guidelines and standards to ensure compatibility between non-electronic monitoring systems and the Ships Data Multiplexing System.

- o Ensure expeditious test and evaluation of the LM-2500 Condition Monitoring System and the FT-9 Engine Condition Monitor, both in the laboratory and at sea, as first test articles for main propulsion machinery.

- o Provide research and development funds to implement the recommendations of the "Feasibility Study for a Diesel Engine Condition Monitoring System for 1179 Class LST's" (National Bureau of Standards Report NBS-GCR 75-43) in at least one ship. This will test and evaluate the effectiveness of another approach in a different class of main propulsion machinery.

Task A-5 - New Technology

New technology can introduce a threat or can yield benefits to both life-cycle costs and system effectiveness. Decisions to acquire systems based upon new technology must be timely, and must be based upon objective consideration of these two possibilities.

In the past, decisions to acquire a system have been based on potential system effectiveness and on initial costs. Experience, however, indicates that life-cycle costs are dominated by operational, miantenance, and logistic expenditures. A new technology assessment and forecasting procedure that emphasizes life-cycle cost and system effectiveness would provide a realistic and cost-effective basis for evaluating new systems. The introduction of new technology should be justified on the basis of well-defined economic factors and on a favorable balance of performance benefits versus risks.

Recommendations

- o Sponsor the development of objective methodologies to guide the introduction of new technology, recognizing the state of associated manufacturing technology. The objective should be to determine:

  - When to acquire new technology and when to invest in research and development of it

  - The risks associated with a new technology

- The associated integrated logistic support requirements.

- o Establish new test standards and methodologies for microprocessors and mass memory devices.

- o Develop advanced built-in-test capabilities for lasers, fiber optics, and imaging devices in order to preclude the complex alignment and repair problems associated with future opto-electronic systems.

- o Initiate research and development of the application of the microprocessor for enhancing the built-in-test capability of future systems.

- o Sponsor a research and development program directed specifically to automated test techniques as they relate to RF and microwave technology.

Task A-6 - Education, Training, and Management

Review of the report on Navy ATE issues (*) specifically indicates that management is a general solution for most automatic-test-equipment problems. It is interesting to note that this is the only case in this report where a single solution crosses all problem areas.

The key to management is people, not procedures. Yet, past efforts have focused upon training operational and maintenance personnel in automatic test equipment, while leaving a serious gap in the training of decision makers within Navy and industry management. This gap will become more pronounced as more advanced technology in automatic test equipment is introduced and implemented within the Navy. There is therefore an urgent need to develop resources for training a broad range of Navy and industry managers in automatic test technology and its applications.

(*)"Report on Navy Issues Concerning Automatic Test, Monitoring, and Diagnostic Systems and Equipment," prepared by RTE Ad Hoc Working Group for the Assistant Secretary of the Navy (R&D), dated February 13, 1976.

Recommendations

- o Develop a comprehensive series of courses on automatic test equipment and related subjects suitable for Navy-wide and industry use.

- o Develop and implement a training program that matches specific personnel classifications to the spectrum of courses developed.

- o Develop selection criteria for use of new instructional media and training aids, for all levels of personnel training. Training technology has made rapid advances (e.g., video systems, smart terminals, simulators), and these developments should be implemented.

Task A-7 - Advanced ATE Concepts

Dramatic progress in semiconductor and in computer technologies has allowed the development of more complex military systems with greater performance capability. In turn, these systems have demanded the development of correspondingly more complex automatic test equipment. In commercial industry, the past few years have been a rapid expansion in the use of automatic test equpment -- such equipment has netted industry a good return on funds invested in it. In the opinion of this Task Group, the Navy can learn valuable lessons from the way automatic test equpment has been used in private industry.

The fleet reports a real and acute need for the next generation of automatic test equpment. Ultimately, it is these users who must assess the degree of this need, and whether it is being satisfied. Many of the firms that supply automatic test equipment and who participated in the work of this Task Group take the position that the off-the-shelf equipment developed by industry can satisfy the Navy's needs without the expense and other drawbacks of developing unique test equipment. However, the consenus of the A-7 Task Group is that the Navy must embark immediately upon a research and development program to provide the next generation of automatic test equipment. A family of functional equipment that will better meet the needs of the Navy is recommended.

Recommendations

- o The Navy should immediately sponsor a continuous research and development program to develop the next generation of automatic test equipment.

- o The Navy should sponsor a study to investigate the optimum use of ATLAS and OPAL test languages, to guide the development of new automatic test equipment systems. A concurrent study should investigate the potentials of graphical programming for the above purpose.

- o The Navy should sponsor a building-block project to develop eight hardware building-blocks, ranging from families of power supplies and switching units to ruggedized key commercial products; from standard operator controls and displays to several new technical concepts for a wide spectrum of applications.

- o The Navy should sponsor a long-range, continuing project to develop advanced test techniques to solve the complex testing problems inherent in new high technology systems.

- o The Navy should sponsor a five-year-project to investigate the basic nature of man-machine interaction. The main body of the Task A-7 report breaks this project down into recommended technical subprojects in various testing disciplines, with participation by maintenance engineers, display experts, and human engineering experts.

- o The Navy should fund and manage a technology center with first emphasis on research and development, to provide means for assimilating and collating the welth of technical data and inforamtion about automatic test equipment, and to assess and forecast the impact of this information.

Task B - ATE Acquisition Planning Guide

The DOD weapon systems acquisition process is a well-defined procedure; however, program managers tend to defer maintenance-related decisions to later phases of the process, beyond the point where such decisions can effectively improve operational readiness and reduce life-cycle costs.

The classic appeal of automated testing has been the advantages of reducing testing time and lowering the technical skills required. This has been superseded by the technological necessity of automatic testing for the support of today's Naval weapon systems. Emerging technology will even more tightly couple automated testing to prime system effectiveness.

There is a lack of practical guidance for porject engineers who must acquire automatic test equipment. The Navy's "ATE Acquisition Planning Guide" is an attempt to fill this present need; it is a step toward alerting program managers to the timing and substance of key automatic-test-equipment decisions. The Task Group reviewed the Guide in draft form.

Recommendations

- The user's understanding of the Guide would be improved by the addition of an overall flow chart that would integrate the several acquisition phases, as they relate to automatic-test-equipment.

- The Guide should present a clear distinction between acquisition functions for prime systems and those for automatic-test-equipment.

- The Guide should apply to built-in testing as well as to stand-along automatic-test-equipment.

- A final draft of the Guide has the above recommendations incorporated, and should be distributed for use by management personnel concerned with automatic-test-equipment acquisition. It is recommended that it be updated after one year of use, an every two years thereafter.

Task C - Built-In-Test Design Guide

The increasing complexity of electronic systems and the shortage of trained maintenance personnel has resulted in excessive repair times. However, the use of built-in-test has tended to reduce this parameter, to the extent that the technique has been applied. A built-in-test design guide is needed to aid both project and design personnel in the optimal use of built-in-test.

The Navy has prepared a draft guide in the form of a handbook. This draft has been reviewed and commented upon by this Task Group and responding industry organizations. The final version is now available.

Recommendations

- Form a permanent committee to review the design guide on an annual basis.

- Require testability and built-in-test design features to be included in future procurements.

- Expand current Navy module level built-in-test studies to include large scale integrated circuits, weapon replaceable assemblies, and subsystems.

- Conduct studies and develop techniques for the retrieval, analysis, and use of malfunction information from avionic fault protection and memory systems.

Task E - ATE Data Banks

Rather than an automatic-test-equipment data bank, the Navy urgently needs an independent cadre of professionals who can provide analysis, consultation, recommendations, and problem-solving on automatic-testing matters, in an objective manner. A data bank would be essential in properly supporting the activities of such a group. It would also be useful to industry for in-depth studies of automatic-testing technology, and for design studies and prototype development making use of the contents and corporate memory of the data bank.

Navy acquisition managers need more accurate, reliable, and timely automatic-test-equipment data. The Navy Research and Development Staff can make effective use of such data for technology forecasts and assessments relative to automated testing.

Recommendations

- The Navy should fund and manage an automatic-test-equipment data bank. This data bank should not be a single, all-inclusive depository physically sited in one location, but rather a network designated as the data bank that takes advantage of and builds upon existing Navy ATE Data Centers. The corporate memory contained in the above listing of data to be stored, if properly used and applied to new programs, will save millions of dollars.

- The task group members were unified in their opinion that a prior condition essential to the establishment of the automatic-test-equipment data bank is that the Navy establish a professional automatic-test-equipment technical group. This group would be charged with structuring the data bank, reviewing and interpreting user requests, interrogating the data bank, interpreting the output, responding to the user, and then answering the user's questions on the response provided.

Task F - Operational Readiness Monitoring Systems (ORMS)

Allowable reaction times to detect, evaluate, and engage an enemy threat have become significantly shorter due to the high-speed performance of present day and near-future weapon systems. At the same time, the lack of real-time system readiness information to commanding officers has been identified as a major problem affecting fleet operations.

An operational readiness monitoring system is required to provide this real-time information. It should be realized that the final system, with all the extended capabilities it requires, is a very ambitious program requiring significant research and development.

Recommendations

- o The Navy should establish an operational-readiness monitoring system program. The objectives of this program should include the following:

  - Establish a quantitative definition of operational readiness

  - Perform a pilot evaluation of an existing ship's subsystem at sea

  - Perform an evaluation on a future ship's subsystem, such as the FFG-7.

- o Due to the complexity and size of the overall program, it should be modular in structure and should be implemented in well-defined phases.

Task H - ATE Interface

This Task Group identified and defined the problems common to automatic-test-equipment-interface designers and users. The goal was to provide the Navy with a consolidated recommendation for interface standards and guidelines. It has been determined that existing guidelines are meager and inadequate; industry agrees that there is little or no standardization of the physical, electrical, and human interfaces of automatic test systems. The effectiveness of such standards, when they are prepared, will be limited until the Navy and the industry recognize testability as a companion requirement of tactical performance.

Recommendations

- o Establish a new interface standard for automatic test systems. Unique testability requirements may dictate that there be separate standards for automatic test equipment associated with avionic support, as opposed to those for maintenance and support of other electronics.

- o Extend the effort of this Task Group to complete the above recommended standard, or assign this effort to a special Navy research and development group.

Task I - Specifications Review

Specifications related to automatic testing were reviewed for content, applicability, and effectiveness. These detailed technical documents were found to be satisfactory for their intended purposes; therefore, the Task Group recommendations are to augment, correct, or refine these specifications, without changing their fundamentally technical nature.

Other Task Groups have suggested cases where research and development activity in areas such as automatic-test-program generation, testability, software managment, microprocessors, and other developing technologies could be more effectively directed if specifications or standards were provided. However, this would be difficult because these are the areas where we do not yet know what to specify in point of approach or performance.

The consideration of automatic-test requirements early in the weapon system acquisition cycle has been found to be essentially a management problem -- this is not the proper concern of technical specifications. This subject is treated in MIL-STD-1388, Logistic Support Analysis, and in the new "ATE Acquisition Guide." These documents, properly used, will cause automatic-testing considerations to be addressed in a timely, effective manner.

Recommendations

- Specifications and standards should not be produced to control the new technologies appearing in automated-testing software and hardware until such emerging technologies have progressed to a point of stability and until definition of obtainable goals is possible.

- Consider the consolidation of individual System Commands' automatic-testing-related specifiations, directives, and procedures into unified NAVMAT or DOD specifications, directives, and procedures.

- Modify existing military specifications and standards to permit increased use of commercial-quality automatic test equipment where

requirements are met by such equipment. However, adequate provision must be made for documentation and configuration control.

- The use of provisional or trial specifications for new technologies may be helpful in channeling industry research and development efforts.

LIST OF ABBREVIATIONS AND ACRONYMS

This list contains abbreviations and acronyms most commonly associated with automatic test equipment.

ADADS	-	Army Depot Automatic Diagnostic System
ADEMS	-	Advanced Diagnostic Engine Monitoring System
ADTS	-	Avionic Depot Test System (Air Force)
AGE	-	Aerospace Ground Equipment
AIDAPS	-	Automatic Inspection, Diagnostic and Prognostic System (Army-Helicopters)
AIDS	-	Airborne Integrated Data System
AIS	-	Avionics Intermediate Shop (Air Force)
ATE	-	Automatic Test Equipment
ATE/ICE	-	Automatic Test Equipment for Internal Combusion Engine (Army)
ATEMS	-	Automatic Test Equipment for Missile Systems (Army)
ATG	-	Automatic Test Generation
ATLAS	-	Abbreviated Test Language for all Systems or Abbreviated Test Language for Avionic Systems
ATPG	-	Automatic Test Program Generation
ATS	-	Automatic Test Systems
ATSS	-	Automatic Test Support System (Army)
ATT	-	Advanced Testing Technology (Navy)
AUDDIT	-	Automatic Dynamic Digital Tester
BIT	-	Built-In Test
BITE	-	Built-In Test Equipment
CAD	-	Computer-Aided Design
CARTE	-	Contact and Repair Test Equipment
CAT	-	Computerized Automatic Test (Navy)
CATE	-	Computer-Controlled Automatic Test Equipment
COMCERTS	-	Combat Systems Certification Site
DACT	-	Digital Automatic Card Tester
DFT	-	Design for Testability
DIMATE	-	Depot Installed Multi-Purpose Automatic Test Equipment (Army)
DITS	-	Digital Integrated Test System

EAGE	-	Electronic Aerospace Ground Equipment
EQUATE	-	Electronic Quality Assurance Test Equipment (AN/USM-410) (Army)
ERF	-	Electronic Repair Facility
ETE	-	Electronic Test Equipment
FDI	-	Fault Detection Isolation
FIT	-	Fault Isolation Test
FLU	-	First Line Unit
FMTS	-	Field Maintenance Test Set (Army-U.S. Roland)
GATE	-	General Purpose Automatic Test Equipment (Army)
GPATS	-	General Purpose Automatic Test System (Army)
HATS	-	Hybrid Automatic Test Station
HOL	-	Higher-Order Language
HWIL	-	Hardware-In-The-Loop
ID	-	Interconnecting Device
IECMS	-	Inflight Engine Monitoring System
ITU	-	Interface Test Adapters
LCSS	-	Land Combat Support System
LRU	-	Lowest Replaceable Unit or Line Replaceable Unit
MADARS	-	Malfunction, Detection, Analysis, and Recording System
MADREC	-	Malfunction, Detection, and Recording Equipment
MAIDS	-	Multipurpose Automatic Inspection and Diagnostic System (Army)
MATE	-	Modular Automatic Test Equipment (Air Force) or Missile Automatic Test Equipment (Army)
NOPAL	-	Non-Operational Performance and Analysis Language
OPAL	-	Operational Performance Analysis Language
OTS ETE	-	Off-The-Shelf Electronic Test Equipment
PAD	-	Passive Automatic Detection
PDU	-	Programmable Diagnostic Unit
PIU	-	Programmable Interface Unit
RU	-	Replaceable Unit
SACE	-	Shore-Based Automatic Checkout Equipment (Navy-Trident)
SAIE	-	Special Acceptance and Inspection Equipment

SATE	-	Special Acceptance Test Equipment
SCCM	-	Self-Checking Computer Module
SIT	-	System Integration Test
SRU	-	Shop Replaceable Unit
STAR	-	Self-Test and Repair
STC	-	System Test Console
STE/ICE	-	Simplified Test Equipment for Internal Combusion Engines (Army)
TEAMS	-	Test, Evaluation, and Monitoring Systems (Navy)
TMDE	-	Test, Measurement, and Diagnostic Equipment
TPS	-	Test Program Set
TRACE	-	Test Equipment for Rapid Automatic Checkout Evaluation
TRME	-	Theatre Readiness Monitoring Equipment (Army-Hawk)
UUT	-	Unit Under Test
VAST	-	Versatile Avionics Shop Test (Navy)

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